Essays on Performance of Insurance Companies

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The President:

Prof. Dr. Thomas Bieger

To my dear parents and brother

Meike, Wolfgang & Yannic

To my dear girlfriend

Kim

Acknowledgments

The cover only lists one author. However, in reality my dissertation would not have been possible, without the great support of numerous people. At this point, I would like to thank all of them.

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Outline

Contents

Executive Summary

This dissertation consists of four parts, and it addresses the performance of insurance companies. The first part analyzes the impact of the business environment on the productivity and efficiency of life insurers. The second part focuses on the interdependencies among growth, profitability, and safety, which are the three main strategic goals of many insurers. The third part examines the role of the capacity for changes in prices and productivity, which determine profitability. The fourth part analyzes the development of the efficiency of stock and mutual insurers over time.

The first part is entitled “Under pressure: How the business environment affects productivity and efficiency of European life insurance companies.” In this part, multi-stage data envelopment analysis (DEA) is applied to a sample of 970 life insurance companies from 14 European countries for the period of 2002–2013 to analyze the impact of the business environment on productivity and efficiency. The results show that general economic, capital market, and insurance market conditions are important drivers of productivity and efficiency in the European life insurance sector. In addition, while no technical change is observed during the sample period, an increase in efficiency leads to an increase in total factor productivity, which can be explained by the challenging business conditions for life insurers during this period. This part presents the first empirical evidence of how business conditions fundamentally affect the operations of life insurance companies.

The second part is entitled “Get the balance right: A simultaneous equation model to analyze growth, profitability, and safety.” In this part, the interdependencies among the three main strategic goals of many insurers are analyzed. The extant literature suggests that the relationships are reciprocal and that conflicting goals constrain the simultaneous maximization of all goals. A simultaneous equation model is developed to test three pairs of hypotheses derived from the literature. The empirical results suggest that some of the relationships are indeed non-linear, and this provides evidence of the existence of conflicting goals. Additional non-parametric analyses also show that trade-offs among the goals exist over time. Consequently, growth, profitability, and safety must be considered simultaneously in a multi-period setup to comprehensively evaluate the performance of insurance companies.

The third part is entitled “The impact of capacity on price and productivity change in insurance markets: New firm-level evidence.” This part examines the role of capacity, which is a mutual determinant of price and productivity. In this part, particular focus is placed on the role of exogenous factors (changes in the interest rate, catastrophes, growth of the gross domestic product, and regulations) for these relationships. The analysis is based on a newly-constructed sample of firm-level data for the German non-life insurance market from 1954 through 2016, making it also the longest productivity study of insurance in the literature. The results show that the impact of capacity on price

is complex and is moderated by exogenous factors. In line with the capacity-constraint hypothesis, the decreased capacities of firms and industry have a positive impact on price. Firms' decreased capacities also have a negative impact on changes in productivity. The results contribute to the understanding of underwriting cycles, and they re-emphasize the role of capacity in the insurance business.

The fourth part is entitled "Stock versus mutual insurers: Long-term convergence or dominance?" In this part, the efficiency of stock and mutual insurers is analyzed over time. Even though the previous literature documents significant differences between the two organizational forms in the 1980s and 1990s, it is posited in this part that changes in the economic environment (e.g., elimination of state aid for the mutual organizational form and the introduction of risk-based capital standards) promote convergence. The analysis of metatechnology technical DEA efficiency on the basis of common econometric convergence measures (β- and σ-convergence) in samples for the U.S. and EU insurance markets indeed provides evidence for converging technologies in the period 2002–2015. Overall, this part shows that, in the current business environment, the organizational forms inevitably may have to converge as expected by some policymakers.

Zusammenfassung

Die vorliegende Dissertation besteht aus vier Teilen, die sich mit der Performance von Versicherungsgesellschaften befassen. Im ersten Teil wird der Einfluss des Geschäftsumfelds auf die Produktivität und Effizienz von Lebensversicherern untersucht. Der zweite Teil konzentriert sich auf die Interdependenzen zwischen Wachstum, Profitabilität und Sicherheit, die drei wesentliche strategische Ziele vieler Versicherer darstellen. Der dritte Teil beleuchtet die Rolle von Unternehmens- und Industriekapazität für unternehmensspezifische Preis- und Produktivitätsveränderungen, welche zusammen die Profitabilität determinieren. Im vierten Teil wird die Entwicklung der Effizienz von Aktienversicherern und Versicherungsvereinen im Zeitverlauf analysiert.

Der erste Teil trägt den Titel „Under pressure: How the business environment affects productivity and efficiency of European life insurance companies." In diesem Abschnitt wird eine mehrstufige Dateneinhüllanalyse (DEA) für ein Sample von 970 Lebensversicherungsunternehmen aus 14 europäischen Ländern für den Zeitraum von 2002 bis 2013 durchgeführt, um den Einfluss des Geschäftsumfeldes auf die Produktivität und Effizienz zu analysieren. Die Ergebnisse zeigen, dass die allgemeinen wirtschaftlichen sowie die Kapitalmarkt- und Versicherungsmarktbedingungen relevante Faktoren für Produktivität und Effizienz im europäischen Lebensversicherungssektor darstellen. Obwohl während des Untersuchungszeitraums kein technischer Fortschritt zu beobachten ist, führt eine Steigerung der Effizienz zu einer Erhöhung der totalen Faktorproduktivität, was anhand der erschwerten Geschäftsbedingungen für Lebensversicherer während des Untersuchungszeitraums erklärt werden kann. Dieser Teil dokumentiert den ersten empirischen Beleg dafür, welchen erheblichen Einfluss die Geschäftsbedingungen auf die Geschäftstätigkeit der Lebensversicherer haben.

Der zweite Teil trägt den Titel „Get the balance right: A simultaneous equation model to analyze growth, profitability, and safety." In dieser Passage werden die Interdependenzen zwischen den drei strategischen Zielen vieler Versicherer analysiert. Die bestehende Literatur suggeriert, dass die Beziehungen wechselseitig sind und dass Zielkonflikte die gleichzeitige Maximierung aller Ziele einschränken. Um drei aus dieser Literatur abgeleitete Hypothesenpaare zu testen, wird ein simultanes Gleichungsmodell entwickelt. Die empirischen Ergebnisse legen nahe, dass einige der Beziehungen nicht linear sind, was auf die Existenz von Zielkonflikten hindeutet. Nicht parametrische Analysen zeigen, dass Zielkonflikte zwischen den Zielen auch im Zeitverlauf bestehen. Folglich müssen Wachstum, Profitabilität und Sicherheit gemeinsam in einem Mehrperioden-Setup berücksichtigt werden, um die Performance von Versicherungsgesellschaften umfassend zu bewerten.

Der dritte Teil mit dem Titel „The impact of capacity on price and productivity change in insurance markets: New firm-level evidence" untersucht die Rolle von

Unternehmens- und Industriekapazität für unternehmensspezifische Preis- und Produktivitätsveränderungen. In diesem Abschnitt wird ein besonderer Schwerpunkt auf die Rolle exogener Faktoren (Zinsänderungen, Katastrophen, Wachstum des Bruttoinlandprodukts und Regulierungen) für diese Beziehungen gelegt. Die Analyse basiert auf einer neu erstellten Stichprobe von Unternehmensdaten für den deutschen Nichtleben-Versicherungsmarkt der Jahre 1954 bis 2016 und ist damit auch die längste Produktivitätsstudie im Versicherungskontext, welche in der Literatur zu finden ist. Die Ergebnisse zeigen, dass der Einfluss der Kapazität auf den Preis komplex ist und durch die exogenen Faktoren moderiert wird. Im Einklang mit der Kapazitätsbeschränkungshypothese haben verringerte Unternehmens- und Industriekapazitäten eine positive Auswirkung auf den Preis. Eine Abnahme der Unternehmenskapazität wirkt sich auch negativ auf die Produktivitätsveränderung aus. Die Ergebnisse tragen zu einem verbesserten Verständnis des Versicherungszyklus‘ bei und akzentuieren die Rolle der Kapazität für das Versicherungsgeschäft.

Der vierte Teil trägt den Titel „Stock versus mutual insurers: Long-term convergence or dominance?“ In diesem Teil wird die Effizienz von Aktienversicherern und Versicherungsvereinen im Zeitverlauf analysiert. Während die bestehende Literatur signifikante Unterschiede zwischen den beiden Organisationsformen in den 1980er- und 1990er-Jahren dokumentiert, argumentiert dieser Teil, dass Veränderungen im Geschäftsumfeld (z. B. Beseitigung staatlicher Beihilfen für Versicherungsvereine und die Einführung von risikobasierten Eigenkapitalstandards) die Konvergenz der beiden Gesellschaftsformen förderten. Die Analyse der technischen Metatechnologie-DEA-Effizienz auf der Grundlage üblicher ökonometrischer Konvergenzmaße (β- und σ-Konvergenz) in Stichproben für die Versicherungsmärkte der USA und der EU liefert Anzeichen für konvergierende Technologien im Zeitraum von 2002 bis 2015. Insgesamt verdeutlicht dieser Teil, dass die Organisationsformen im aktuellen Geschäftsumfeld zwangsläufig konvergieren sollten, wie es auch von politischen Entscheidungsträgern erwartet wird.

Synopsis

The first paper is entitled "Under pressure: How the business environment affects productivity and efficiency of European life insurance companies." This paper is co-authored with Martin Eling, who is affiliated with the University of St. Gallen in Switzerland. The paper was published in the *European Journal of Operational Research*, Vol. 258, 2017, pp. 1082–1094.

The previous insurance literature has considered changing economic conditions to be the causes for the development of productivity and efficiency of European life insurers (e.g., Cummins & Rubio-Misas, 2006; Vencappa, Fenn, & Diacon, 2013; Biener, Eling, & Wirfs, 2016). This paper is the first to analyze explicitly the links between the business environment and productivity and efficiency in the life insurance sector. It contributes to the increasing number of innovative data envelopment analysis (DEA) applications, such as the inclusion of uncontrollable variables (Yang & Pollitt, 2009; Huang & Eling, 2013), two-stage bootstrapping procedures (Barros, Nektarios, & Assaf, 2010), relational two-stage DEA modeling (Kao & Hwang, 2008, 2014), and cross-frontier analysis (Biener & Eling, 2012). The analysis is particularly relevant because the life insurance sector has experienced significant economic changes in the recent past (e.g., internationalization, low interest rates). The main contribution of this paper is the empirical analysis of life insurers' exogenous productivity and efficiency determinants. In addition, it shows the interaction between the business environment and firms' characteristics, both of which are determinants of productivity and efficiency. Overall, the aim of this paper is to advance the understanding of the productivity and efficiency of life insurance companies.

Abstract of "Under pressure: How the business environment affects productivity and efficiency of European life insurance companies": Deregulation and widespread economic changes have fundamentally affected the business environment of European life insurance companies over the last decades. We apply multi-stage data envelopment analysis to identify the impact of the changing environment on productivity and efficiency of European life insurance companies. Considering a sample of 970 life insurance companies from 14 European countries, we show that general economic, capital market, and insurance market conditions are important drivers of efficiency. Although we find no technical change in the European life insurance sector, we nonetheless observe an efficiency increase in 2002–2013 that leads to an increase in total factor productivity; these trends can be explained by more challenging business conditions in the 2000s. Our results emphasize the need to control for the business environment in cross-country efficiency studies.

The second paper is entitled "Get the balance right: A simultaneous equation model to analyze growth, profitability, and safety." This paper is a joint work with Martin Eling and Ruo Jia at Peking University in the People's Republic of China. It was published in the *University of St. Gallen School of Finance Working Paper Series (No. 2017/16)*.

Many insurance companies attempt to determine the optimal balance among the dimensions of growth, profitability, and safety. In their 2014 annual reports, 11 of the 15 largest European insurance companies claim “profitable growth” as a strategic goal. In addition, safety is particularly important in insurance due to regulatory requirements and because policyholders are sensitive to the risks that the firm might incur. Although the extant literature suggests that the relationships among these three dimensions are reciprocal, the extent of their interdependencies is not fully understood. Conflicting goals can be found in the literature, and they constrain the simultaneous maximization of all goals. To the best of the authors’ knowledge, this paper is the first to analyze the interdependencies among growth, profitability, and safety simultaneously. In this context, tests for non-linearity are used to determine whether conflicting goals exist. Also, non-parametric analyses are used to examine the interdependencies over time. The results indicate that growth, profitability, and safety must be considered simultaneously in a multi-period setup to comprehensively evaluate performance.

Abstract of “Get the balance right: A simultaneous equation model to analyze growth, profitability, and safety”: We develop a simultaneous equation model to test the reciprocal relationships among growth, profitability, and safety. Analyzing 1,988 European insurance companies over eleven years, we find that moderate firm growth increases profitability and reduces firm risk; however, extremely high growth reduces profitability and increases risk. In addition, we document that less profitable companies are risk-seeking, a result in line with prospect theory. Our longitudinal analyses illustrate that firms initially prioritizing profitability over growth are more likely to reach the ideal state of “profitable growth”.

The third paper is entitled “The impact of capacity on price and productivity change in insurance markets: New firm-level evidence.” This paper is co-authored with Martin Eling and Robert E. Hoyt, who are affiliated with the University of St. Gallen in Switzerland and the University of Georgia in the U.S., respectively. It was published in the *University of St. Gallen Working Papers On Risk Management and Insurance (No. 200)*.

Underwriting cycles and productivity are the two fields that have been addressed most often in the insurance literature. Even though there has been a great amount of previous research, there is no definitive conclusion on the causes of the price fluctuations that have been observed in the insurance industry. Also, despite theoretical foundations (e.g., Grifell-Tatjé & Lovell, 2015), links between the two topics have yet to be analyzed. This paper contributes to the literature in two ways. First, it provides additional information on the role of capacity, which is a mutual determinant of price and productivity. For this purpose, a new sample of cross-sectional data was created that allows disentangling firm capacity from industry capacity. This analysis is relevant because the literature lacks cross-sectional studies on underwriting cycles in general, and the two existing studies (Cummins & Danzon, 1997; Weiss & Chung, 2004) reach different conclusions regarding the impact of capacity. With regards to productivity, the role of capacity has not been analyzed to date in the insurance literature. Second, the long sample period (1954–2016) allows the analysis of the impact of exogenous factors that are identified as relevant moderators in the literature, i.e., interest rate changes, catastrophes, GDP growth, and regulations.

Abstract of "The impact of capacity on price and productivity change in insurance markets: New firm-level evidence": We find evidence for the capacity-constraint hypothesis in a newly constructed sample of firm-level data for the German non-life insurance market over an extended period (1954–2016). Moreover, we show that the impact of capacity on price is complex and depends on various exogenous factors (interest rate change, catastrophes, GDP growth, and regulation). We also find that decreased firm capacity has a negative impact on productivity change. The dual impact of capacity is important since price and productivity change determine firm profitability. Our results yield important implications for the understanding of underwriting cycles and re-emphasize the role of capacity in the business of insurance.

The fourth paper is entitled "Stock versus mutual insurers: Long-term convergence or dominance?" This paper was published in the *University of St. Gallen Working Papers On Risk Management and Insurance (No. 201)*.

This paper focuses on the implication of the organizational form on performance, a topic that has attracted significant attention in the insurance literature. The previous theoretical standpoint was that either stock insurers dominate in terms of efficiency (i.e., the expense preference hypothesis, EPH) or that both organizational forms dominate in different market segments (i.e., the efficient structure hypothesis, ESH). Empirically, the EPH has not gained much support, but several studies found evidence for the ESH in samples for the 1980s and 1990s. In the EU, discussions have emerged recently concerning whether the operations of stock and mutual insurers still differ and whether the organizational forms have started to converge (Broek et al., 2011). The convergence assumption arises from developments in the business environment (e.g., elimination of state aid for the mutual organizational form and the introduction of risk-based capital standards), and these developments suggest changes, particularly in the way mutual insurers operate. These developments also have occurred in the U.S., where the empirical evidence supports the convergence hypothesis. A.M. Best (2012) shows that the performance of stock and mutual insurers in the U.S. property and casualty insurance sector is aligned directionally in the period 2001–2011; insurers stood out in terms of operating performance and capitalization irrespective of the organizational form. This paper, which analyzes whether the state of different production technologies between stock and mutual insurers is persistent over time, contributes to the formulation and empirical testing of the convergence hypothesis.

Abstract of "Stock versus mutual insurers: Long-term convergence or dominance?": I find evidence for convergence of stock and mutual insurers in an analysis of metatechnology efficiency estimated by data envelopment analysis in samples for the U.S. and EU from 2002 to 2015. This result may emphasize that, contrary to findings of previous literature, the dominance of the two organizational forms declines over time. Recent changes in the economic environment (for example, elimination of state aids for the mutual organizational form and introduction of risk-based capital standards) may explain this result. Unlike previous studies focusing on the expense preference and efficient structure hypotheses, I consider the dynamics of stock and mutual insurers' technology and efficiency.

As reflected in this dissertation, the performance of insurance companies is characterized by various dimensions. The aim of this dissertation is to advance the understanding of their performance by contributing to four relevant research issues. In doing so, it considers both conventional financial ratios, such as the return on equity, and innovative frontier productivity and efficiency measures (see Cummins & Weiss, 2013, for an introduction and overview). Apart from the common umbrella, the four papers are linked in three specific ways.

First, a significant focus is on the role of exogenous factors with the aim of explaining performance by also considering the economic context. The first paper reviews the exogenous factors that influence the productivity and efficiency of life insurers, empirically analyzes the directions of their impacts, and outlines how to account for these factors in frontier measurement. The third paper shows that the capacity-price relationship is moderated by exogenous factors, suggesting that the interaction of capacity and changes in these factors can cause underwriting cycles. The fourth paper was motivated by recent changes in the economic context for stock and mutual insurers, leading to the hypothesis that these changes account for the documented convergence of the two organizational forms.

Second, the papers attach great emphasis on using dynamic analysis elements, which provide important insights, such as the fact that performance is not a steady state process (Viswanathan & Cummins, 2003). The first paper analyzes the impact of changes in the business environment on changes in productivity. The second paper analyzes the interdependencies among growth, profitability, and safety over time and contextualizes the results with the contemporaneous relationships. The third paper analyzes rare, firm-level data, which partially were hand-collected over 63 years, allowing the longest productivity analysis in the literature to date. The fourth paper provides the first dynamic analysis of the use of technology by stock and mutual insurers.

Third, this dissertation takes a further step toward understanding the interdependencies among different performance dimensions. The second paper shows that the relationships among growth, profitability, and safety are reciprocal, and it demonstrates empirically that some of the relationships are non-linear (quadratic), suggesting that goal conflicts exist. Part three examines the role of capacity, a mutual determinant of price and productivity, both of which influence profitability.

In addition to its academic contribution, this dissertation delivers important insights to several stakeholders. The documented results will be particularly helpful for the management of companies and useful for analysts, investors, and regulators for assessing the performance of insurance companies. The identification of the exogenous drivers of the efficiency and productivity of life insurers is valuable to predict changes in firm behavior. Specifically, the results show that adverse business conditions tend to force managers to conduct more productivity-enhancing activities (e.g., cost-savings programs). The identification of conflicts between the goals of growth, profitability, and safety helps managers determine the right balance between the three dimensions, and it is helpful for other stakeholders to evaluate performance in a multi-dimensional and temporal contexts. The results of the impact of capacity can be considered in forecasting and analyzing alternative scenarios, which is particularly important for the market entry and exit strategies of insurance companies. The documented convergence trends of stock and mutual insurers in this dissertation is relevant particularly for regulators and policymakers since they generally promote the coexistence of the stock and mutual organizational forms, but convergence may cause insurers to forsake their inherent advantages, especially mutual insurers.

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Part I

Under Pressure: How the Business Environment Affects Productivity and Efficiency of European Life Insurance Companies

MARTIN ELING and PHILIPP SCHAPER

Abstract

Deregulation and widespread economic changes have fundamentally affected the business environment of European life insurance companies over the last decades. We apply multi-stage data envelopment analysis to identify the impact of the changing environment on productivity and efficiency of European life insurance companies. Considering a sample of 970 life insurance companies from 14 European countries, we show that general economic, capital market, and insurance market conditions are important drivers of efficiency. Although we find no technical change in the European life insurance sector, we nonetheless observe an efficiency increase in 2002–2013 that leads to an increase in total factor productivity; these trends can be explained by more challenging business conditions in the 2000s. Our results emphasize the need to control for the business environment in cross-country efficiency studies.

Keywords: Data envelopment analysis · Multi-stage DEA · Uncontrollable variables · Insurance

JEL classification: G22 · L29

This paper was published in *European Journal of Operational Research*, Vol. 258, 2017, pp. 1082–1094. It was presented at the 2015 World Risk and Insurance Economics Congress in Munich, the 2015 Annual Meeting of the German Finance Association in Leipzig, and the 2016 Annual Congress of the German Insurance Science Association in Vienna. We thank Semir B. Ammar, Christian Biener, Ruo Jia, Kim Straub, Jan H. Wirfs, and the conference participants for valuable comments and suggestions. We also thank three anonymous referees for their helpful suggestions.

1 Introduction

The 1994 deregulation of the financial services industry and widespread economic changes, such as internationalization and low interest rates, signify significant competitive pressure for European life insurers. More competitive markets bring pressure on productivity and efficiency, forcing firms that are unable to adapt to state-of-the-art technology to be displaced. Bad underwriting practices are further penalized because these can no longer be compensated by high capital market returns. Moreover, the increased divergence of business conditions across European countries since the financial crisis has placed additional pressure on the financial services industry. Many central European economies (e.g., Germany) have been relatively robust to the crisis, while some Southern European countries have shown negative growth rates (OECD, 2014; European Commission, 2015). In addition, European markets have experienced divergent interest rate developments, with relatively low overall interest rate levels but significant increases in some countries, such as Italy, Ireland, and Spain (see, e.g., Barrios, Iversen, Lewandowska, & Setzer, 2009; Lane, 2012).

Previous studies have observed changes in productivity and efficiency for either the entire European life insurance industry or the industries of single countries and have attributed these developments partially to changing environmental conditions. Vencappa, Fenn, and Diacon (2013) document negative annual technical change rates in the European life insurance industry in a period of significant shocks to capital markets (i.e., 1996–2008). Cummins and Rubio-Misas (2006) find technical regress for the Spanish life and non-life insurance industries in 1989–1998 and highlight that the costs of adjusting to new environmental conditions might lead to a slippage in the production frontier. Furthermore, Biener, Eling, and Wirfs (2016) find significant technical regress and total factor productivity (TFP) decline for the Swiss life insurance market between 1997 and 2013, and attribute it to an increasingly challenging business environment of low interest rates and increased competition from other financial service providers, such as banks. However, no prior study has explicitly investigated the links between productivity and changes in the business environment.

We analyze the impact of the major environmental challenges (regulations, capital market developments, and competition) on productivity and efficiency of European life insurance companies in 2002–2013 using a new innovative measurement approach. The innovative element is that we incorporate uncontrollable variables in multi-stage data envelopment analysis (DEA), an approach that enables us to identify which parts of productivity and efficiency changes are due to the environment and which aspects are due to managerial ability. Owing to data limitations, the focus of the analysis is on technical and cost efficiency.

To the best of our knowledge, only one study has so far considered the impact of uncontrollable variables on efficiency in an insurance context. Huang and Eling (2013) analyze the efficiency of non-life insurance companies in Brazil, Russia, India, and China (BRIC bloc of countries) and document that the environment strongly affects the efficiency of non-life insurers operating in these countries. We build upon and expand their analysis using an analysis of the life insurance sector and consider the European marketplace. The application of this methodology to European life insurance is especially meaningful given the widespread economic changes that have fundamentally affected the business environment in recent decades—the sample (selected time period and countries) covers the complete economic cycle (i.e., upturn, turmoil, and recovery) and comprises economic divergence between the different operating environments. Thus, we contribute to the growing number of innovative DEA applications, such as the inclusion of uncontrollable variables (Yang & Pollitt, 2009; Huang & Eling, 2013), two-stage bootstrapping procedures (Barros, Nektarios, & Assaf, 2010), relational two-stage DEA modeling (Kao & Hwang, 2008, 2014), and cross-frontier analysis (Biener & Eling, 2012). Moreover, we are the first to analyze the impact of economic maturity, unemployment, and stock market performance on life insurers' efficiency.

The main contribution of our empirical analysis is that it shows how the business environment affects life insurers' productivity and efficiency; to this end, we consider general economic, capital market, and insurance market conditions. As a by-product, we analyze the interaction between the business environment and firm-specific characteristics—namely, how size, ownership, and solvency impact technical and cost efficiency before and after controlling for the business environment. Finally, we illustrate how the productivity and efficiency of the European life insurance sector develops over time. Given the increasingly difficult and more heterogeneous business environments, we expect productivity to decline and efficiency to increase over our sample period.

We analyze 970 life insurance companies (7,149 firm years) from 14 European countries for 2002–2013, which makes this study one of the largest DEA analyses ever conducted on life insurance. Our findings can be summarized as follows. We show that general economic, capital market, and insurance market conditions are important drivers of efficiency. More specifically, the results reveal that economic maturity and stock market performance are positive drivers of efficiency whereas regulation (i.e., capital adequacy) and unemployment are negatively associated with efficiency. Inflation and interest rate level have different impacts on technical (negative) and cost efficiency (positive). We show that, owing to comparatively low interest rates, good stock market performance, and low inflation, Switzerland has the least inefficiency caused by the business environment and Ireland has the highest inefficiency due to the business environment, and these results reflect the economic development of these markets in recent years. Our findings emphasize the importance of controlling for environmental impacts, especially with reference to other cross-country studies that do not control for the development of the operating environment (e.g., Eling & Luhnen, 2010a; Biener & Eling, 2012).

Finally, we show that the best practice frontier in the market does not change over the sample period but significant technical efficiency improvement causes TFP to increase. These trends can be explained by more challenging business conditions for European life insurers. By contrast, Huang and Eling (2013) note a decrease in efficiency in the BRIC countries in times of overall favorable market conditions, which did not require efficiency improvements. Our result of no technical change in the life sector mirrors country-specific findings for Spain (see Cummins & Rubio-Misas, 2006) and Switzerland (see Biener et al., 2016) where business conditions have even caused technical regress.

Our findings are useful for insurance managers, regulators, and policymakers to enhance the understanding of the driving forces behind productivity and efficiency of the European life insurance industry. The results are useful for defining productivity and efficiency effects due to changes in the business environment and managerial improvements. In addition, the findings provide a relevant reference for other jurisdictions outside Europe and other industries, such as banks and pension funds, which are exposed to the same business challenges as European life insurers. While the results of the present study might be generalized to other countries and sectors, there are also more particular reasons for focusing on the European life insurance sector—that is, the abovementioned changes have triggered a critical phase of transition that questions the business model and sustainability of the entire industry (see, e.g., BaFin, 2014; IMF, 2015, 2016a). The high economic importance of the sector even leads to systemic risk concerns about overall economic well-being (IMF, 2016b); thus, the life insurance sector per se warrants particular attention.

The remainder of the paper is organized as follows. In Section 2, we discuss the theoretical background and our hypotheses. Section 3 presents the methodology and data. Section 4 presents the empirical results and, finally, we conclude in Section 5.

2 Background and hypotheses

Traditionally, efficiency studies implicitly assume that inefficiency is caused by bad management and occurs under identical environmental conditions (Yang & Pollitt, 2009). However, in a cross-country setting, this assumption should be questioned as management controls only factors internal to production; the environment is not under its control. If the impact of uncontrollable variables is not considered, the efficiency of firms in an adverse external environment could be underestimated. We incorporate this aspect by using multi-stage DEA. The consideration of uncontrollable variables in estimation is widespread in banking (see, e.g., Dietsch & Lozano-Vivas, 2000; Lozano-Vivas, J. T. Pastor, & J. M. Pastor, 2002; Fries & Taci, 2005; Liu & Tone, 2008), while in insurance, its application is limited to one study from the non-life sector (Huang & Eling, 2013). Thus, our study is the first to apply this methodology in a life insurance context.

The new institutional economics literature argues that institutional aspects (e.g., legal and political factors) influence companies' conduct (see, e.g., North, 1986). Thus, differences in these "rules of the game" may account for divergent performance of corporations domiciled in different countries. Rajan and Zingales (2003) emphasize the importance of such institutional aspects for explaining cross-country differences in financial market developments. We examine the role of environmental factors for the life insurance industry. One recent study by Cummins, Rubio-Misas, and Zi (2015) shows that integration and performance in the European life insurance sector are affected by financial market development, competition, as well as legal and government systems and, as such, underlines the relevance of our research. Because environmental factors have not been considered comprehensively for life insurers' efficiency and productivity specifically, the derivation of hypotheses and selection of variables is oriented toward previous empirical studies from the banking industry (e.g., Lozano-Vivas et al., 2002). We consider three central dimensions constituting the business environment of life insurers: general economic, capital market, and insurance market conditions (see Dietsch & Lozano-Vivas, 2000; Lozano-Vivas et al., 2002; Huang & Eling, 2013). Within these three dimensions, we analyze seven components in detail; four of these have been analyzed already in the insurance literature, while three have not yet been analyzed, to the best of our knowledge. In this section, we discuss the theoretical relationship between each environmental dimension and efficiency, present extant empirical evidence (if it exists), and consequently, formulate our hypotheses (see Table 1 for an overview). In most cases, our hypotheses follow the same line of reasoning: adverse business conditions force managers to conduct more productivity-enhancing activities (e.g., cost-savings programs). Moreover, adverse conditions and productivity improvements force inefficient firms to leave the market, resulting in a smaller variation of productivity and higher efficiency levels on average.

Table 1 Hypotheses and extant literature

Hypothesis	Specification	Extant Insurance Literature
H1: General economic conditions		
H1a: Economic maturity	Positive relationship between GDP per capita and efficiency.	Not yet analyzed in existing literature.
H1b: Unemployment	Positive relationship between unemployment rate and efficiency.	Not yet analyzed in existing literature.
H1c: Inflation	Negative relationship between inflation and efficiency.	Huang and Eling (2013)
H2: Capital market conditions		
H2a: Interest rate level	Negative relationship between interest rate level and efficiency.	Huang and Eling (2013)
H2b: Stock market performance	Positive relationship between stock market performance and efficiency.	Not yet analyzed in existing literature.
H3: Insurance market conditions		
H3a: Competition	Negative relationship between competition and efficiency.	Bikker and Van Leuvensteijn (2008); Choi and Weiss (2005); Berry-Stölzle, Weiss, and Wende (2011)
H3b: Regulation	Negative relationship between regulation (i.e., capital adequacy) and efficiency.	Huang and Eling (2013)

H1a: Economic maturity

Various authors (Dietsch & Lozano-Vivas, 2000; Lozano-Vivas et al., 2002; Kasman & Yildirim, 2006) have emphasized the importance of macro-economic factors (population density, density of demand, and per capita income) as environmental constituents for the banking industry's technical, cost, and profit efficiency. While population density and density of demand—used to proxy the costs of providing banking services—are less relevant for life insurers owing to less distinct branch networks, per capita income is relevant as a proxy for market maturity (see, e.g., Enz, 2000). Countries with high income per capita are assumed to have a more mature banking sector, resulting in competitive profit margins (see, e.g., Dietsch & Lozano-Vivas, 2000). In growing markets and under expansive demand conditions, companies feel less pressured to control their costs, but there is greater pressure to engage in productivity-enhancing activities if the market is mature and demand conditions are strict (see, e.g., Maudos, Pastor, Perez, & Quesada, 2002).[1] Although existing customers in some cases might be restricted in switching life insurers due to punitive surrender terms, low potential for new business might force inefficient life insurers to leave the market in the long run. Thus, we expect a positive link between GDP per capita and efficiency.

H1b: Unemployment

Unemployment is an adverse driver of life insurance demand, especially in the context of lapse: the higher the unemployment rate is, the higher the lapse rate is (see, e.g., Eling & Kochanski, 2013). This is the so-called emergency fund hypothesis. Two potential consequences are the incurred loss due to high upfront investments (Pinquet, Guillén, & Ayuso, 2011) and the additional loss of future profits (Eling & Kiesenbauer, 2014). In addition, economies of scale could be used as an argument for this hypothesis. If the number of contracts decreases due to lapse, then fixed costs have to be allocated across a smaller number of contracts, which, *ceteris paribus*, increases the cost ratio. In a scenario with high lapse, more liquidity is needed, which reduces the investment return potential. Thus, lapsing challenges both liquidity and profitability (see, e.g., Kuo, Tsai, & Chen, 2003). Therefore, it is especially important for life insurers to control costs and productivity in an environment with relatively high lapse rates. Poorly managed firms with high lapse rates will be the first to disappear in a high lapse scenario. Thus, high lapse should force increases in productivity and efficiency. Therefore, we expect a positive relationship between unemployment and efficiency.

H1c: Inflation

In the non-life insurance industry, inflation increases the costs of claims (see, e.g., Cummins & Tennyson, 1992). However, this is not expected in the life insurance industry, as most mortality, wealth accumulation, and longevity protection policies have benefits that are fixed in nominal terms, and typically only morbidity products (e.g., disability and long-term care) are adjusted more frequently for the rise of costs of living (Swiss Re, 2010). However, given that life insurance benefits are not adjusted for inflation, higher inflation might have an eroding effect on demand (see Neumann, 1969). Clark (1982) discusses inflation-induced efficiency losses, highlighting how the inflation process affects relative prices and their perception by consumers. The higher is the level of inflation, the higher is the perceived inflation risk. Hence, higher levels of inflation should be challenging for life insurers, thereby putting pressure on their operations. Initial empirical evidence for the insurance industry

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1 Macro-economic conditions influence a variety of factors related to the demand and supply side (see, e.g., Semih Yildirim & Philippatos, 2007). Various studies (see, e.g., Fortune, 1973; Headen & Lee, 1974; Enz, 2000; Zietz, 2003) have examined the relationship between macro-economic factors and life insurance demand. Note that the link between macro-economic development and demand should be positive, but it might be linear or non-linear (see, e.g., the S-curve in Enz, 2000). Jahromi and Goudarzi (2014) show that in the long run, there is a causal relationship between GDP per capita and insurance penetration ratio (one measure for insurance market maturity).

confirms this relationship (see Huang & Eling, 2013). Therefore, we expect a negative relationship between inflation and efficiency.

H2a: Interest rate level

Interest income constitutes one of the main profit sources of life insurance companies, given that in most countries, the majority of funds are invested in interest-bearing instruments (see Appendix A). For decades, a common strategy of life insurers was to buy safe bonds with long-term maturity and relatively high interest rates.[2] A high interest rate environment offers a relatively high degree of freedom as interest income may improve revenue efficiency and compensate for bad underwriting as well as higher costs. However, in a low interest rate environment, insurance companies have to be very strict in their underwriting and cost management, as bad underwriting and inefficient cost structures can no longer be compensated for with high capital market returns. Lower interest rates put special pressure on life insurance products with guaranteed interest payments (see, e.g., Grosen & Jørgensen, 2000). Moreover, lower interest rates, *ceteris paribus*, increase liabilities (present value of future payments) (Briys & De Varenne, 1997), which puts pressure on the balance sheet. In theory, other impacts are conceivable, especially in the context of the reinsurance structure, but to the best of our knowledge, these are rare in practice and are difficult to analyze owing to data limitations. For the non-life insurance industry, Huang and Eling (2013) identify a negative connection between the interest rate level and efficiency. Given the theoretical arguments and empirical results, we expect a negative link between the interest rate level and efficiency.

H2b: Stock market performance

Because stock returns are also a profit component for life insurers, the economic rationale for the derivation of H2b could be the same as for the interest rate level (i.e., the higher the return, the higher is income and the lower is the need for cost savings). However, stock investments make up a smaller portion of life insurers' portfolios (see Appendix A); therefore, stock returns are less relevant than interest income. Other aspects related to stock market performance, besides the income component, might be more relevant. Lorson and Wagner (2014) find that, under good stock market conditions (i.e., when stock markets regain momentum), the decision of which life insurer to choose is influenced by the total return offered to policyholders (i.e., shares of capital income,

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2 This previously common strategy is becoming problematic given the low interest rate environment because long-term investments that come to term have to be replaced by bonds carrying much lower interest rates. Against this background, the minimum interest rate guarantee and further product options, which are especially prevalent in life insurance contracts, are difficult to maintain. Carson, Elyasiani, and Mansur (2008) document the interest rate sensitivity of life insurers. Eling and Kochanski (2013) discuss the importance of interest rates for the profitability and lapse of life insurers (the interest rate hypothesis). Berdin and Gründl (2015) demonstrate that a prolonged period of low interest rates noticeably affects the solvency situation of life insurers, leading to a relatively high cumulative probability of default, especially for less capitalized insurers.

underwriting, and cost results). Furthermore, existing and potential new policyholders may consider alternatives to life insurance products if products with higher investment returns are available in the market. Thus, life insurers that offer higher total returns can attract more policyholders. In addition, improving cost structures and underwriting results to increase total returns when stock markets show positive long-term performance should be reflected in increased productivity. Therefore, we expect a positive link between stock market performance and efficiency.

H3a: Competition

In line with many studies, we consider seller concentration as an important determinant of the competitive structure of the insurance market (see, e.g., Joskow, 1973; Bikker & Van Leuvensteijn, 2008). Leibenstein (1966) and Demsetz (1973) provide theoretical foundations for the relationship between competition and efficiency. Leibenstein (1966) argues that X-inefficiencies (i.e., firms do not exploit their full efficiency potential) might exist due to less motivational force. Sparse competitive pressure, for example, due to high seller concentration, can evoke such a lack of motivation; in other words, more competitive pressure could enhance efficiency. However, a reverse relationship between competition and efficiency can be inferred from Demsetz (1973), who defines the efficient-structure hypothesis. According to this hypothesis, firms' efficiency determines the structure of the market in which they operate. Because more cost-efficient firms can charge lower prices, they can gain more market share.[3] This hypothesis, in contrast to Leibenstein's theory, implies a negative relationship between competition and efficiency, if higher concentration is a result of greater efficiency (see, e.g., Fenn et al., 2008). Divergent empirical evidence supporting both theories can be found for the insurance industry. For example, Bikker and Van Leuvensteijn (2008) examine the Dutch life insurance sector and document high levels of X-inefficiencies, determining that this may be a consequence of relatively insufficient competitive pressure. This finding supports a positive relationship between competition and efficiency. On the contrary, Choi and Weiss (2005) find evidence in favor of the efficient-structure hypothesis for the U.S. property/liability insurance market. In addition, Berry-Stölzle et al. (2011) support the efficient-structure hypothesis in the European property-liability insurance market. Based on the competing theoretical foundations and these divergent results, the relationship between competition and insurer efficiency is ambiguous. However, following the empirical results for the complete European insurance sector, we expect a negative relationship between competition (in terms of seller concentration) and efficiency.

[3] However, this effect is expected to materialize only if product quality is maintained. Moreover, reductions in prices should be motivated by cost efficiency gains; otherwise, inadequate pricing could have deleterious effects in the long run (e.g., unexpected loss expenses in the future due to insufficient reserving).

H3b: Regulation (capital adequacy)

Regulation in the insurance sector mainly is concerned with avoiding insolvencies. Like other studies, we consider the industry average of equity to assets as an indicator of capital adequacy (see, e.g., Huang & Eling, 2013 for insurance; Dietsch & Lozano-Vivas, 2000 for banking). Increased security levels associated with higher equity-to-asset ratios come at the expense of costly equity capital and consequently, higher costs of capital.[4] Because equity capital is one of the inputs in efficiency measurement, an increase in equity, reflected in an increase of solvency ratios, *ceteris paribus*, leads to a reduction in productivity. However, if the increase in equity applies to the entire industry, the impact on efficiency is not trivial.[5] Furthermore, regulation may impose more reporting, compliance, and risk management activities, which cause high costs and constrain management decisions. Moreover, higher capital adequacy probably causes higher market-entry barriers (see, e.g., Barth, Lin, Ma, Seade, & Song, 2013). Thus, the impact of regulation (capital adequacy) on efficiency may be negative. On the other hand, regulation may prevent companies from engaging in risky activities (i.e., in underwriting or on the investment side), and thus, may encounter efficiency problems (Lozano-Vivas et al., 2002). Another possible argument is that, in the long run, increased security levels might result in an increased premium volume, because policyholders should value low levels of insolvency risk (see, e.g., Wakker, Thaler, & Tversky, 1997; Epermanis & Harrington, 2006). These arguments rather imply a positive relationship between capital adequacy and efficiency; this direction of relationship also is found generally in the banking literature (see, e.g., Pasiouras, 2008; Chortareas, Girardone, & Ventouri, 2012; Barth et al., 2013). However, existing empirical evidence provided by Huang and Eling (2013) shows that capital adequacy is an adverse driver of technical efficiency in the non-life insurance industry. Thus, we follow the empirical evidence for the insurance industry and expect a negative relationship between regulation (i.e., capital adequacy) and efficiency.

3 Methodology and data

3.1 Methodology

We adapt the multi-stage DEA approach introduced by Fried, Schmidt, and Yaisawarng (1999) and control for environmental conditions on a per-country as well as per-annum basis in order to obtain cross-country efficiency scores that fully reflect managerial efficiency. The multi-stage approach is preferred over a "one stage

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4 The interaction with other risk management instruments needs to be mentioned here. Higher required capital can be accounted for by changes in reinsurance, asset allocation, or underwriting strategy. In our analysis, we control for such differences as these different strategies affect both inputs and outputs. For example, with more reinsurance, incurred losses are lower, and less equity capital is needed.

5 If, for example, a proportional loading is added to the existing equity capital (e.g., every insurer has to hold 10% more equity capital), then efficiency remains unchanged. If a fixed loading were added (e.g., every insurer has to hold 1 million USD more equity capital), then efficiency could either increase or decrease.

approach" as outlined, for example, in Cooper, Seiford, and Tone (2007), since the latter procedure requires the classification of the environmental variables as inputs or outputs (Yang & Pollit, 2009). Thus, the researcher has to make a priori assumptions on whether the variable represents favorable or unfavorable operating conditions (Fried et al., 1999). However, the links between the business environment and efficiency are not so well understood that it is possible to make solid a priori assumptions. In addition, compared to the traditional DEA, companies may become more efficient in a one-stage model only because the number of variables included in the model increases (Yang and Pollit, 2009). For our purpose, we consider that it is more suitable to use the multi-stage DEA model, as the empirically observed links between the business environment and efficiency are the result of the analysis instead of a priori assumptions. In addition, this approach enables us to identify those countries with the least and most favorable business environments during the sample period. Furthermore, the procedure allows inferences about whether the business environment in the European life insurance sector overall had a beneficial (i.e., efficiency enhancing) or adverse impact. However, to demonstrate how our contribution could be exploited further, in Appendix B we present a one-stage DEA model taking into account the inferences from our analyses about whether the selected environmental variables are favorable or unfavorable.

DEA measures firm productivity against the productivity of best-practice firms, which determine the efficient frontier (Charnes, Cooper, & Rhodes, 1978). We estimate input-oriented frontiers with constant returns to scale to measure technical efficiency (TE) and variable returns to scale to measure pure technical efficiency (PTE); in addition, we measure scale efficiency (SE), allocative efficiency (AE), and cost efficiency (CE). We rely on Simar and Wilson's (2000) bootstrapping approach to estimate bias-corrected efficiency scores and, therefore, account for sample variations. Due to data limitations, we cannot estimate revenue and profit efficiency, especially because it is not possible to estimate firm-specific prices. For example, estimating the price of the output investments would require information about the asset structure of each life insurer, which is not available in our data. The estimation of the technical efficiency of N decision-making units (DMUs, i.e., firms) using M inputs to produce K outputs is illustrated by the following linear programming problem (refer to Cummins and Weiss, 2013, for the estimation of PTE, SE, AE, and CE):

$$TE_j = \min \theta_j \text{, s.t. } \lambda_j X \leq \theta_j x_j \text{, } \lambda_j Y \geq y_j \text{, } \lambda_j \geq 0 \ (j = 1,2,3......N) \text{,}$$

where TE represents Farrell's (1957) measure of technical efficiency for DMU j ($j = 1,2,...,N$), θ is a scalar providing a radial distance estimate for DMU j, X is an $M \times N$ matrix of all inputs used by N DMUs, Y is a $K \times N$ matrix of all outputs produced by N DMUs, x_j is an $M \times 1$ input vector for DMU j, y_j is a $K \times 1$ output vector, and λ_j is an $N \times 1$ intensity vector of DMU j. We estimate cross-country frontiers—namely, efficiency is measured relative to a European benchmark.

There are two sources of inefficiency in the standard DEA approach: differences in firm management and differences in business environments. To control for differences in the business environments and comparing only pure managerial efficiency, we conduct the following four stages. The first stage is the previously described standard DEA with commonly used inputs and outputs (Model 1). In the second stage, total input slacks are regressed[6] against a set of uncontrollable variables representing the business environment.[7] In the third stage, the initial input values from the first stage are adjusted with respect to the impact of the environmental variables resulting from the second stage (i.e., companies that operate in a favorable environment are penalized with higher input values, which, *ceteris paribus,* reduces efficiency). Finally, in the fourth stage, we rerun the DEA model based on the adjusted input values from the third stage (Model 2).

In addition, we analyze the impact of the environmental conditions and firm characteristics on technical and cost efficiency in truncated regression analyses. This procedure allows for the testing of the impact (significant or insignificant) and direction (positive or negative) of these environmental factors on European life insurer efficiency. We choose a truncated regression procedure, rather than a censored (tobit) analysis, because both the studies of Simar and Wilson (2007) and McDonald (2009) argue that tobit is, in general, an inconsistent estimator in the context of efficiency scores. In robustness checks (see Appendix D), we apply ordinary least squares, tobit, and fractional regression models, all of which have been considered in second-stage regressions in the literature (E. A. Ramalho, J. J. Ramalho, & Henriques, 2010) and which provide consistent results.

The development of efficiency and productivity over time is analyzed by (1) window analysis and (2) estimating input-oriented Malmquist indexes of TFP (see, e.g., Cummins & Weiss, 2013). We follow Simar and Wilson (1999, 2000) and use bootstrapping for these approaches in order to obtain robust results. TFP changes are further decomposed into its two central sources: technical change and technical efficiency change. Furthermore, technical efficiency change is divided into two components: pure technical efficiency change and scale efficiency change. Alternatively to the Malmquist indexes, a dynamic model with intertemporal production frontiers, as described by Färe and Grosskopf (1996), may be used. However, the advantages of our procedure are the simplicity and computational ease (i.e., it is not necessary to define, argue, and assume production nodes) as well as the comparability with prior insurance

[6] Following Fried, Lovell, Schmidt, and Yaisawarng (2002), we use a stochastic frontier analysis (SFA) slack regression. Alternatively, a truncated slack regression approach could be used in the second stage (Huang & Eling, 2013). However, the inherent methodological advantage of the SFA approach is that it accounts not only for the effects of statistical noise but also for managerial inefficiency (Fried et al., 2002; Yang & Pollit, 2009). The SFA slack regression results are given in Appendix C.

[7] Through this procedure, so-called allowable input slacks due to the business environment can be obtained. The allowable input slacks mean that a certain amount of input waste is acceptable because it is caused by an adverse external environment, not by managerial inefficiency. The remaining input slacks represent management's excessive use of inputs.

literature, which has widely used Malmquist indexes to analyze productivity developments (see e.g., Mahlberg & Url, 2010; Bertoni & Croce, 2011; Biener et al., 2016). Furthermore, using Malmquist indexes allows the estimation of not only efficiency and technical change over time but also its combined impact on TFP. On the other hand, the Malmquist indexes do not investigate the production process in detail and are less flexible—that is, they do not consider connecting activities (e.g., carry-overs) between periods. However, as indicated earlier in this subsection, the dynamic approach requires the formulation of production nodes and the ex-ante specification of exact input–output relations (including the specification of the environmental variables), which we consider rather as a result of than as an input of the study, and goes beyond the current scope of this study. Nonetheless, in Appendix E we illustrate term efficiencies in 2002–2013 following the model proposed by Lu, Wang, and Kweh (2014), which is, to the best of our knowledge, the first approach to implement a dynamic DEA model in an insurance setting; the inferences from this model are consistent with our conclusions. We consider the further development of the dynamic model for insurance companies as beyond the scope of the study but the analysis of environmental factors is an important contribution to understanding the life insurance production process.

3.2 Data

We consider all life insurers included in the Insurance Reports database of A.M. Best (2002–2013) and domiciled in Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom during the sample period of 2002–2013. The selection of countries and sample period is oriented to the availability of data; for this reason, some European countries (e.g., Greece, Hungary, Poland, Portugal, and Spain) are not included in the analysis. Norway and Switzerland are not members of the European Union (EU), but they were included since bilateral agreements with the EU make life insurers from those countries potential competitors of EU insurers. Both the sample period and selection of countries are meaningful bases for our type of analysis, as they comprise periods of economic convergence and upturn (i.e., 2002–2006/7), turmoil (i.e., the financial crisis post 2007) and recovery (i.e., in the early 2010s). Furthermore, the sample period accounts for the anticipated introduction of Solvency II, an EU directive that codifies and harmonizes EU insurance capital adequacy, with the launch of the formal legislative process in 2007. Composite insurers were excluded from the sample. Extreme data, such as zero or negative total asset values, were eliminated from the sample. For comparative purposes, all numbers were deflated to 2002 and converted into US dollars; consumer price indexes and exchange rates were obtained from AXCO Insurance Information Services. The final sample consists of 970 life insurance companies (7,149 firm years).

Table 2 presents summary statistics on the inputs, input prices, outputs, environmental variables, and firm characteristics. In addition, Appendix F shows the distribution of the sample across countries, time, and ownership types. The summary statistics again emphasize the heterogeneity between the external environments and underline the importance of taking these aspects into account in efficiency measurements. For example, we observe a large variation in the market maturity proxy (GDP per capita) across countries and especially over time. The minimum value of 21,307 (Italy, 2002) is more than four times lower than the maximum value of 114,834 (Luxembourg, 2011).

Table 2 Summary statistics (mean values and standard deviations [in parentheses])

Variable	Austria	Belgium	Denmark	Finland	France	Germany	Ireland	Italy	Luxembourg	Netherlands	Norway	Sweden	Switzerland	United Kingdom
Inputs														
x1: number of employees in 1,000s	0.92	0.23	0.10	0.73	1.60	1.54	1.97	5.97	0.72	3.89	2.10	2.20	1.65	6.84
	(0.96)	*(0.29)*	*(0.19)*	*(0.62)*	*(4.96)*	*(3.57)*	*(2.65)*	*(11.77)*	*(1.13)*	*(10.80)*	*(2.33)*	*(4.37)*	*(3.17)*	*(18.77)*
x2: debt capital in bn USD	2.23	0.77	3.65	6.94	8.06	5.49	4.21	5.70	3.18	8.69	13.95	10.10	14.27	19.52
	(2.20)	*(2.24)*	*(5.01)*	*(8.77)*	*(12.79)*	*(13.94)*	*(10.19)*	*8.83*	*4.33*	*17.64*	*14.47*	*12.45*	*28.57*	*41.34*
x3: equity capital in bn USD	0.06	0.03	0.41	0.56	0.36	0.10	0.22	0.24	0.06	0.77	0.93	4.17	0.60	0.91
	(0.05)	*(0.09)*	*(0.49)*	*(0.89)*	*(0.53)*	*(0.19)*	*(0.40)*	*(0.41)*	*(0.04)*	*(1.61)*	*(0.92)*	*(7.01)*	*(1.43)*	*(1.68)*
Outputs														
y1: benefits + changes in reserves in bn USD	37.26	37.15	37.62	38.61	38.63	37.95	37.85	38.60	37.91	38.33	39.71	38.68	39.41	41.01
	(0.44)	*(1.16)*	*(1.12)*	*(2.77)*	*(3.56)*	*(2.94)*	*(2.08)*	*(3.83)*	*(1.40)*	*(3.18)*	*(4.62)*	*(3.23)*	*(5.06)*	*(10.72)*
y2: total invested assets in bn USD	2.05	0.75	3.96	6.92	7.82	5.19	3.24	5.40	2.89	8.66	14.42	13.77	14.04	17.60
	(2.00)	*(2.26)*	*(5.21)*	*(8.57)*	*(12.45)*	*(12.88)*	*(6.43)*	*(8.11)*	*(4.19)*	*(17.60)*	*(14.93)*	*(17.55)*	*(28.15)*	*(39.28)*
Input prices														
p1: price of labor in 1,000s USD	54.48	52.84	103.88	49.87	62.06	73.01	49.76	29.52	83.54	53.96	80.03	68.25	109.91	55.13
	(18.92)	*(10.87)*	*(20.43)*	*(9.74)*	*(12.62)*	*(12.54)*	*(12.67)*	*(2.40)*	*(22.06)*	*(8.52)*	*(28.46)*	*(14.94)*	*(22.71)*	*(9.08)*
p2: price of debt capital in %	0.04	0.04	0.04	0.04	0.04	0.03	0.05	0.04	0.03	0.04	0.04	0.04	0.02	0.04
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*
p3: price of equity capital in %	0.08	0.10	0.11	0.16	0.11	0.09	0.05	0.08	0.07	0.12	0.08	0.14	0.12	0.10
	(0.01)	*(0.02)*	*(0.00)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*
General economic conditions														
GDP: economic maturity in 1,000 USD	40.65	39.10	50.88	40.39	37.39	37.89	48.07	31.78	91.66	43.21	80.47	46.09	61.19	36.88
	(8.23)	*(7.46)*	*(9.04)*	*(7.51)*	*(6.29)*	*(5.94)*	*(7.51)*	*(4.65)*	*(20.90)*	*(7.56)*	*(18.76)*	*(8.55)*	*(14.52)*	*(5.08)*
UNE: unemployment in %	0.07	0.08	0.05	0.08	0.09	0.08	0.08	0.08	0.04	0.13	0.03	0.07	0.03	0.06
	(0.00)	*(0.00)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.04)*	*(0.02)*	*(0.01)*	*(0.04)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*
INF: inflation (CPI, 2002=100)	1.11	1.11	1.10	1.07	1.10	1.10	1.13	1.12	1.13	1.10	1.12	1.07	1.04	1.10
	(0.08)	*(0.09)*	*(0.08)*	*(0.06)*	*(0.06)*	*(0.06)*	*(0.07)*	*(0.08)*	*(0.09)*	*(0.09)*	*(0.07)*	*(0.05)*	*(0.03)*	*(0.10)*
Capital market conditions														
IR: interest rate level in %	0.04	0.04	0.04	0.04	0.04	0.03	0.05	0.04	0.03	0.04	0.04	0.04	0.02	0.04
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*
MSCI: stock market performance in %	0.08	0.10	0.11	0.16	0.11	0.09	0.05	0.08	0.07	0.12	0.08	0.14	0.12	0.10
	(0.01)	*(0.02)*	*(0.00)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*
Insurance market conditions														
COMP: competition in %	0.61	0.65	0.51	0.82	0.48	0.42	0.72	0.53	0.71	0.62	0.85	0.52	0.72	0.39
	(0.13)	*(0.03)*	*(0.02)*	*(0.03)*	*(0.01)*	*(0.02)*	*(0.08)*	*(0.04)*	*(0.12)*	*(0.04)*	*(0.03)*	*(0.07)*	*(0.02)*	*(0.05)*
SOLV: regulation in %	0.04	0.08	0.14	0.08	0.08	0.09	0.14	0.07	0.03	0.11	0.09	0.30	0.09	0.11
	(0.01)	*(0.02)*	*(0.02)*	*(0.01)*	*(0.02)*	*(0.03)*	*(0.03)*	*(0.01)*	*(0.00)*	*(0.01)*	*(0.02)*	*(0.06)*	*(0.04)*	*(0.02)*
Firm characteristics														
OWN: ownership (1=stock, 0=mutual)	1.00	0.88	0.42	0.63	0.89	0.63	1.00	1.00	1.00	0.87	0.90	0.82	0.91	0.98
	(0.00)	*(0.33)*	*(0.49)*	*(0.48)*	*(0.31)*	*(0.48)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.34)*	*(0.30)*	*(0.39)*	*(0.28)*	*(0.14)*
SIZE: size in billion USD	2.57	0.88	4.61	8.08	9.36	6.17	5.05	6.65	3.80	10.47	16.72	15.34	15.70	23.35
	(2.58)	*(2.43)*	*(6.22)*	*(10.25)*	*(14.85)*	*(15.63)*	*(11.98)*	*(10.16)*	*(5.45)*	*(21.50)*	*(17.60)*	*(19.79)*	*(31.79)*	*(51.30)*
$SOLV_i$: solvency in %	0.06	0.08	0.14	0.08	0.08	0.08	0.13	0.06	0.03	0.11	0.08	0.32	0.08	0.10
	(0.04)	*(0.07)*	*(0.11)*	*(0.06)*	*(0.11)*	*(0.16)*	*(0.18)*	*(0.09)*	*(0.04)*	*(0.10)*	*(0.06)*	*(0.24)*	*(0.10)*	*(0.13)*

Inputs and input prices

We follow the literature and use the number of employees (x_1), debt capital (x_2), and equity capital (x_3) as inputs (see, e.g., Huang & Eling, 2013). As the number of employees is not available in the data, we divide total operating expenses from the Best's Insurance Reports database by country-specific prices of labor (as many other studies do; see, e.g., Cummins, Rubio-Misas, & Zi, 2004; Fenn et al., 2008). The price of labor (p_1) was obtained from the International Labor Organization, which collects data on the average annual wages for either financial and insurance activities or financial intermediation activities. The few missing values in the ILO data were estimated by linear interpolation. Long-term interest rates obtained from the OECD are used as a proxy for the price of debt (p_2). For the price of equity (p_3), we consider 15-year rolling returns on MSCI country-specific stock market indexes. The MSCI does not provide an index for Luxembourg and thus, we use the MSCI Europe stock market index for this country. The definition of prices follows other studies, such as Bikker and Gorter (2011) and Cummins and Weiss (2013).

Outputs

For the selection of outputs, we follow Cummins and Weiss (2013) and use the value added-approach. The three services that insurers provide are risk-pooling/bearing services, intermediation, and financial services. We use net benefits plus changes in reserves as the first output variable (y_1) and total invested assets as the second output variable (y_2). Both losses and total invested assets are highly correlated with the third service of insurers (financial services) and thus, generally are not modeled as a separate output (see, e.g., Eling & Luhnen, 2010b). Because DEA is not capable of working with negative values and y_1 can become negative if changes in reserves are negative, we shift this output variable for the compete sample to obtain only non-negative values for y_1 (see Biener et al., 2016).

Uncontrollable (environmental) variables

The selection process for the environmental variables is oriented according to the banking literature (e.g., Dietsch & Lozano-Vivas, 2000; Lozano-Vivas et al., 2002; Fries & Taci, 2005; Liu & Tone, 2008) and the non-life insurance study of Huang and Eling (2013). Whenever appropriate, we make reasonable adaptions to the life insurance context. All variables are measured per annum and per country—that is, all life insurers operating in the same country show the same corresponding uncontrollable variable value in each year.

For the general economic conditions, we follow Dietsch and Lozano-Vivas (2000) and proxy the economic maturity by GDP per capita (GDP). We use yearly mean unemployment rates as a measure of unemployment (UNE). Similar to Huang and

Eling (2013), we include inflation (INF) and measure it by consumer price indexes. Regarding the capital market conditions, we use OECD long-term interest rates as an indicator of the interest rate level (IR) and 15-year rolling returns of country-specific MSCI indexes to measure stock market performance (MSCI). Regarding the insurance market conditions, we use the concentration ratio at the four-firm level (CR4; see, e.g., Huang & Eling, 2013) to measure competition (COMP). This measure is the sum of the market shares held by the four largest insurers in each country, in terms of gross written premiums (see, e.g., Cummins et al., 2004; Fenn et al., 2008); the higher is CR4, the more concentrated and less competitive is the market. The premium data for the competition measure are obtained from Insurance Europe. In addition, we use the country average of equity capital to total assets (based on book values) to represent differences in capital adequacy (SOLV) among countries (see, e.g., Lozano-Vivas et al., 2002; Kasman & Yildirim, 2006).

Firm characteristics

In order to examine how firm characteristics influence the efficiency of European life insurers, we investigate selected firm factors in the truncated regression procedure. We measure ownership (OWN) by binary variables, where a value of 1 is allocated to stock and 0 to mutual companies. Size (SIZE) is measured in terms of total assets. Solvency ($SOLV_j$) is integrated by the firm-specific ratio of capital and surplus to total assets.

4 Empirical results

4.1 Efficiency measurement

Table 3 shows average bias-corrected TE and CE scores for Models 1 and 2 per country as well as for the total sample. The efficiency scores of Model 1 are based on unadjusted input values (stage 1). The efficiency scores of Model 2 reflect efficiency after controlling for the business environment (i.e., using adjusted input values for the stage 4 DEA). PTE, AE, and SE scores are given in Appendix G.

Table 3 DEA efficiency scores

	Model 1		Model 2		Delta (Model 2 - Model 1)	
Country	TE	CE	TE	CE	TE	CE
Austria	0.92	0.59	0.87	0.58	-0.05***	-0.02
Belgium	0.90	0.57	0.85	0.55	-0.05***	-0.01
Denmark	0.97	0.71	0.95	0.70	-0.02***	-0.01
Finland	0.94	0.67	0.87	0.63	-0.07***	-0.04***
France	0.90	0.63	0.86	0.62	-0.04***	-0.01
Germany	0.93	0.58	0.89	0.57	-0.04***	-0.01
Ireland	0.83	0.41	0.85	0.51	0.02*	0.10***
Italy	0.93	0.55	0.92	0.56	-0.01	0.01
Luxembourg	0.93	0.64	0.90	0.59	-0.03	-0.05
Netherlands	0.93	0.54	0.90	0.54	-0.03***	0.00
Norway	0.97	0.67	0.93	0.67	-0.04***	0.00
Sweden	0.95	0.45	0.94	0.46	-0.01	0.01
Switzerland	0.92	0.47	0.83	0.48	-0.09***	0.01
United Kingdom	0.83	0.56	0.82	0.59	-0.01	0.03***
Total Sample	0.91	0.57	0.88	0.58	-0.03***	0.01

Notes: Test of significance is based on a two-sample t-test (two-tailed) with the null hypothesis that the true difference in means is equal to 0. ***, **, and * represent significant differences in means at the 1%, 5%, and 10% levels, respectively.

Model 1 implicitly assumes that all companies operate under the same environmental conditions. In this situation, TE is relatively high. For example, the mean of TE across all countries and years is 0.91, showing that European life insurers on average could improve TE by 9 percentage points. For CE, there is much more room for improvement. The average CE score is 0.57, meaning that there is on average 43 percentage points of improvement potential. One explanation for the relatively low CE levels (in contrast to TE) is the high variance of input prices across the sample countries, which causes large variations when comparing actual costs against minimal costs in the DEA optimization process. For example, the average labor input price for Italy (29,520 USD) is almost four times less than the highest average labor price (109,910 USD, Switzerland). Regarding the variation across countries, Denmark and Norway have the highest TE values, followed by the two other Northern European countries, Sweden and Finland. The finding that these countries have relatively efficient life insurers is in line with Eling and Luhnen (2010a), who analyze life insurer efficiency in 36 countries, including all countries in our sample. At the bottom range in terms of TE are Ireland and the United Kingdom, which are 14 percentage points less efficient than Denmark and Norway (Table 3). In addition, Denmark, Norway, and Finland have the highest CE values; Sweden’s CE level, on the other hand, is below the sample average. The least cost efficient country is Ireland, which is 30 percentage points less efficient than Denmark. Overall, the CE variation across countries has changed in comparison to Fenn et al. (2008), who find that Austrian (British) insurers operated the most (least) efficiently during 1995–2001.

Controlling for the business environment (Model 2) decreases the average TE level in the sample significantly; on the other hand, the increase in average CE is insignificant. In addition, the order of countries is rearranged in Model 2. The largest decrease in TE (-0.09) can be observed for Switzerland, illustrating that this country obtained the highest input adjustments (see Appendix H); in terms of CE, Finland shows the largest decrease. In addition, Austria, Belgium, and Finland have high adjustments, revealing that the environmental conditions in these countries caused comparatively low inefficiency. Meanwhile, Irish life insurers have the least favorable conditions (i.e., inefficiency might be due to the business environment); both TE and CE are higher in Model 2. This result might be explained by the relatively severe post-2008 economic downturn of Ireland. Appendix I illustrates that Irish insurers had the least input adjustments post-financial crisis and thus, the least favorable business environment. Hence, the efficiency of life insurers operating in this country should be underestimated in Model 1, while Model 2 provides a more realistic picture of the actual managerial performance. In Model 2, Denmark is still the most efficient country in terms of TE and CE.

4.2 Regression analysis

In Table 4, we investigate the relationship between the efficiency scores of Models 1 and 2 as dependent variables and the environmental variables and firm characteristics.[8]

Table 4 Truncated regression results

	Model 1 (unadjusted)		Model 2 (adjusted)	
	TE	CE	TE	CE
Regression of environmental conditions				
General economic conditions				
GDP	-0.002	0.025***		
	(0.004)	(0.007)		
UNE	0.004	-0.039***		
	(0.003)	(0.005)		
INF	-0.032***	0.069***		
	(0.005)	(0.009)		
Capital market conditions				
IR	-0.020***	0.021***		
	(0.003)	(0.006)		
MSCI	0.014***	0.083***		
	(0.003)	(0.005)		
Insurance market conditions				
COMP	0.007***	-0.026***		
	(0.002)	(0.004)		
SOLV	-0.007***	-0.064***		
	(0.002)	(0.004)		
Year fixed effects/constant term	YES	YES		
Observations	7,006	7,006		
Regression of firm characteristics				
OWN (stock=1, mutual=0)	-0.021***	-0.055***	-0.021***	-0.054***
	(0.002)	(0.002)	(0.001)	(0.003)
SIZE	0.004**	0.048***	0.005***	0.059***
	(0.002)	(0.003)	(0.002)	(0.003)
$SOLV_j$	-0.010***	-0.092***	-0.005***	-0.066***
	(0.002)	(0.003)	(0.002)	(0.003)
Year fixed effects/constant term	YES	YES	YES	YES
Observations	7,006	7,006	7,006	7,006

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. TE=technical efficiency, CE=cost efficiency. We use Farrell efficiency scores as dependent variables and apply a truncated regression model with left truncation at 0 and right truncation at 1. The dependent variables are truncated at the 99th percentile. The independent variables are mean centered and scaled by their standard deviations.

8 Our regression analysis approach is as follows. First, we regress environmental factors on the efficiency scores of Model 1. Second, we regress firm characteristics on these efficiency scores. We do not use a joint regression model for either variable type (environmental and firm-specific), because we seek to analyze the impact of firm characteristics before and after controlling for the business environment. Incorporating both types in one model would yield coefficients for the firm characteristics after controlling for the impact of the environmental characteristics (for the sake of completeness, we also estimate a joint regression model, which provides consistent results that are available from the authors upon request). Third, we regress firm characteristics on the efficiency scores of Model 2.

Economic maturity. We proxy economic maturity by GDP per capita (GDP) and expect a positive relationship to efficiency (H1a). Table 4 confirms this expectation for CE: the coefficient is positive and significant. For TE, the coefficient of GDP is insignificant. Therefore, companies tend to enhance cost efficiency in more mature markets if the potential for new business is low. For the developing BRIC countries, Huang and Eling (2013) find a negative link between GDP growth and efficiency, showing that under expansive demand conditions, efficiency is not a major concern of insurers. These results could be discussed further in light of a non-linear link between GDP and efficiency, especially regarding the S-curve of Enz (2000). Overall, we find support for H1a only for CE.

Unemployment. Unemployment (UNE) is considered a central driver of lapse. Because lapsed policies can negatively affect life insurers' liquidity and profitability, especially if lapse occurs early during the contract period, we expect a positive relationship with efficiency. However Table 4 reveals no relationship between UNE and TE; the coefficient of UNE is insignificant. For CE, Table 4 shows a negative and significant coefficient, which is different to our expectations. One explanation for this finding is that insurers with higher lapse in high unemployment scenarios experience profits rather than losses. For example, Gatzert, Hoermann, and Schmeiser (2009) state that insurers generally have benefitted from involuntary lapse (i.e., due to insufficient premium payments). High unemployment may cause a higher amount of involuntary lapse. If insurers on average record profit from lapse, they could be less incentivized to be more cost efficient, thereby explaining the negative relationship with CE. Overall, we cannot confirm H1b.

Inflation. Inflation (INF) is measured by consumer price indexes. We expect a negative relationship between inflation and efficiency (H1c). Table 4 confirms this expectation for TE. Hence, we find evidence for inflation-induced technical efficiency losses; unlike with non-life insurance, these might be due to falling demand (see, e.g., Clark, 1982), and are not due to increased costs of claims. For CE, Table 4 reveals a significant and positive relationship. This finding is contra-intuitive given that, *ceteris paribus*, costs of production should increase owing to higher costs of capital and wages. However, this result could be discussed further in light of anticipated and unanticipated inflation—namely, if the inflation increase was anticipated by companies, it is likely that they have already responded accordingly by, for example, price surcharges (see, e.g., Babbel, 1981) or cost cutting. Another potential reason is that higher operating costs are overcompensated by higher asset returns—for example, profit from more valuable real estate investments (see, e.g., Fama & Schwert, 1977; Swiss Re, 2010)—thereby initially reducing the need to improve cost efficiency. Overall, we can confirm H1c only for TE.

Interest rate level. The expected negative relationship (H2a) is revealed for TE, as shown in Table 4, indicating that European life insurers operate more efficiently in lower interest rate environments, probably to compensate for lower interest income and to adapt to the difficult business environment. Meanwhile, the coefficient for CE is positive and significant, which might be explained by the fact that interest rates determine the price of debt;[9] with declining interest rates, the cost of production decreases and thus, productivity increases, while the impact on efficiency is negative in general.[10] Therefore, an interest rate increase has a negative impact on TE, but encourages firms to choose more cost-optimal input combinations because the costs of production increase. Therefore, we find support for H2a, but only for TE.

Stock market performance. For the stock market performance measure MSCI, Table 4 reveals a positive relationship for both TE and CE, thereby supporting H2b. When stock markets are performing well, insurers seem to be encouraged to operate more efficiently (e.g., by optimizing cost structures). Increasing total returns offered to policyholders in this way as a response to competition from other life insurers and alternative product providers is one potential explanation. To obtain further insights into the relationship, especially in the context of country-specific stock market development, we build two subsamples for countries with relatively high and low stock market capitalization and repeat the analysis (see Appendix K). The results indicate that good stock market performance is a positive driver of efficiency only in countries with developed stock markets, where customers may have a more open attitude toward stock investments. In the other subsample, stock market performance seems to play no significant role, and the coefficient of MSCI is insignificant for both TE and CE. The results could be discussed further regarding the financing aspect of stock markets on efficiency.

Competition. In line with the empirical findings for the insurance industry, we expect a negative relationship between competition (COMP) and efficiency. This expectation implies a positive coefficient for COMP, as increases in COMP are in accordance with the assumption of competition losses. Table 4 reveals a positive and significant coefficient for TE. Hence, increases in COMP, implying a less competitive market structure, have a positive impact on TE. Considering both the summary statistics (Table 2) and the efficiency results (Table 3) shows there are high TE levels especially for countries with relatively high levels of COMP, such as Norway, Finland, and Switzerland. However, for CE, the coefficient is significant and negative. Thus, the results do not consistently support H3a.

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9 The technical explanation for this finding stems from the fact that the interest rate level is one determinant of the isocost line slope, which yields a cost-efficient input combination. If the interest rate level increases, the tradeoff between equity (in general, the more expensive input) and debt becomes, *ceteris paribus*, less relevant in determining the cost-efficient input combination. As a result, insurers with high equity levels also tend to become more efficient; the overall effect in our sample is positive (for an illustration, see Appendix J).

10 If, for example, interest rates decline by 100 basis points, the costs of production decrease by a fixed amount and, thus, productivity increases. If the output is unaffected, the efficiency (relative productivity between the companies) might either increase or decrease. See footnote 5 for the same discussion in a different context.

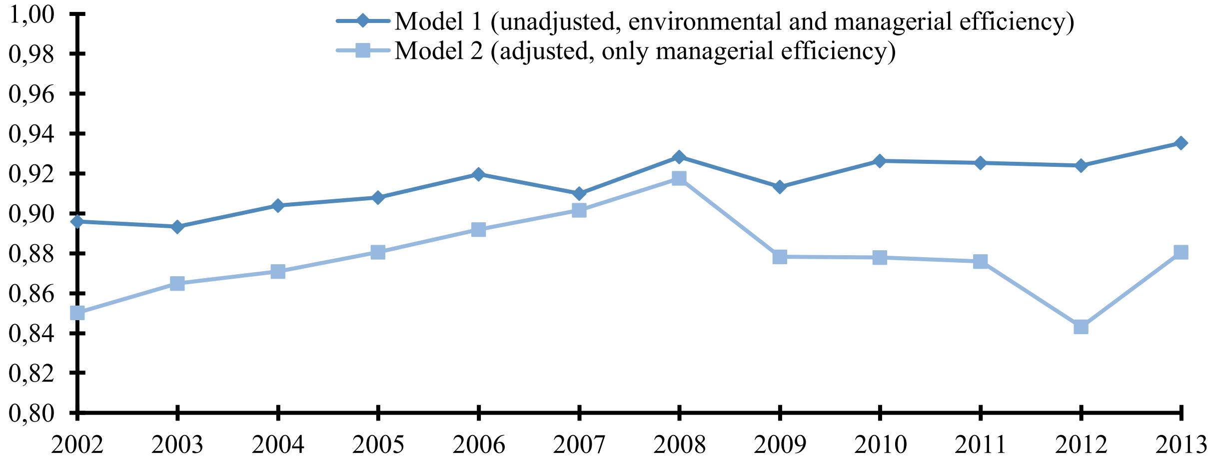
Regulation (capital adequacy). We use the country average of equity to total assets (SOLV) to analyze differences in capital adequacy. Based on a theoretical discussion and existing empirical evidence for the non-life insurance sector, we expect a negative relationship between capital adequacy and efficiency, which is confirmed by Table 4; the coefficient of SOLV is negative and significant for both TE and CE. To obtain further insights on the impact of capital adequacy, especially in the context of the anticipated introduction of Solvency II, which was finally effective from January 2016, we carry out a two-period test (see Appendix L)—that is, we analyze the impact of capital adequacy before and after the launch of the formal legislative process in 2007. The results suggest that the impact of capital adequacy on CE is consistently negative for the two sub-periods. This shows that higher capital adequacy forces life insurers to hold more costly equity capital, which constrains companies attempting to find (cost-)optimal input combinations. Therefore, capital adequacy seems to be a constraint for life insurers in choosing optimal input combinations from a cost perspective. For TE, we find a positive impact of capital adequacy before 2007. This may be explained by the fact that in times of looser capital adequacy, the risk of bankruptcy incentivizes firms to operate more efficiently (see, e.g., Rees, Kessner, Klemperer, & Matutes, 1999). However, through the anticipation of Solvency II, the number of reporting, compliance, and risk management activities increase, which not only cause high costs but also constrain management decisions and thus, may explain the negative impact on TE after 2007, which is also found for the complete sample period. Overall, we find empirical evidence supporting H3b.

Considering the firm characteristics, Table 4 documents that mutual insurers are both more technical and more cost-efficient than stock insurers both in Model 1 and 2. More empirical analyses are needed to derive firm conclusions on this topic, but our general finding—that mutuals are better than stocks—is in line with Biener et al.'s (2016) finding for the Swiss life insurance market, Luhnen's (2009) finding for the German non-life market, and Biener and Eling's (2012) finding for the European and U.S. life and non-life markets. Our results do not confirm the expense preference hypothesis, but might provide some indication for the managerial discretion hypothesis. For a detailed discussion of these hypotheses, refer to Biener and Eling (2012). Furthermore, Table 4 shows that increasing the size of operations has a positive impact on TE and CE for Model 1; the positive size expansion effect also holds after controlling for the business environment (Model 2). Therefore, we conclude that size expansion tends to increase TE and CE. For the firm-specific solvency measure (SOLVj), we find a negative relationship with TE and CE in Model 1, which holds also after controlling for the business environment (Model 2). Cummins and Nini (2002), who analyze capitalization of the U.S. property/liability insurance industry from 1993 to 1998, find that most insurers significantly overutilize equity capital. An overutilization of equity capital leads to significant costs of capital, resulting in efficiency losses.

4.3 Development of productivity and efficiency over time

In this subsection, we show how productivity and efficiency develop under heterogeneous environmental conditions (Model 1) and homogeneous conditions (Model 2). Figure 1 presents yearly average bias-corrected TE scores for the total sample and depicts the development of efficiency in the European life insurance sector over the sample period.

Figure 1 Development of efficiency over time



Notes: Figure 1 is based on average TE scores for the total sample estimated according to Simar and Wilson's (2000) bootstrapping approach in order to account for sample variations.

Figure 1 illustrates that average efficiency in the European life insurance sector increases over the sample period (Model 1). More divergent and challenging business conditions that increasingly placed more pressure on life insurers could explain the efficiency progress. For the developing BRIC countries, on the other hand, Huang and Eling (2013) note a decrease in efficiency from 2000 to 2008 in the non-life industry and trace this back to overall favorable market developments, which did not require focusing on efficiency-enhancing activities. Furthermore, Model 2 shows that, during the pre-crisis period (i.e., 2002–2007), business environments converged in the sample (Model 2 TE levels approached Model 1 efficiency levels). However, after 2008, the differences between Model 1 and Model 2 became larger. Appendix I shows the yearly average input adjustments by country during the sample period. This reveals that post-financial crisis countries were affected differently by their business environment, causing higher input adjustments to level the environmental impacts. If only one country had been experiencing relatively bad environmental conditions, all other countries would have been penalized with the same proportional input adjustment and the net effect on efficiency for the total sample should have been marginal. However, if environmental conditions across all countries had varied widely, input adjustments would not have been proportional and countries would have been penalized differently, thereby causing a significant reduction in the efficiency levels of Model 2 in our sample. After 2012, however, Model 2 TE efficiency levels started to approach Model 1 levels again, illustrating the recommencement of converging business conditions.

To further investigate the development of efficiency and productivity over time, we analyze TFP changes and its sources (i.e., technical and technical efficiency changes) by input-oriented Malmquist indexes. Table 5 presents mean (arithmetic and geometric) annual changes and changes for the complete sample period (average changes per country are given in Appendix M). The results are presented separately for Models 1 and 2.

Table 5 Malmquist index of total factor productivity

Period	Average no. of firms	Technical change	Technical efficiency change	Pure technical efficiency change	Scale efficiency change	TFP Change
Model 1: Unadjusted						
Annual change (arithmetic mean)	541	1.00	1.01***	1.01***	1.00***	1.01***
Sample period: 2002–2013	324	1.00	1.04***	1.05***	1.00	1.04***
Pre-crisis period: 2002–2007	444	1.00	1.05***	1.03***	1.02	1.05***
Post-crisis period: 2008–2013	384	1.01	1.01**	1.01*	1.00	1.02**
Model 2: Adjusted for the environment						
Annual change (arithmetic mean)	541	1.00**	1.01***	1.01***	1.00**	1.00**
Sample period: 2002–2013	324	0.99	1.01	1.03***	0.98***	1.00
Pre-crisis period: 2002–2007	444	1.01***	1.07***	1.05***	1.03**	1.07***
Post-crisis period: 2008–2013	384	0.99**	0.97***	0.98**	0.99***	0.96***

Notes: Test of significance is based on a two-tailed *t*-test using the bootstrapped Malmquist indexes. ***, **, and * represent significant differences from unity at the 1%, 5%, and 10% levels, respectively. For illustrative purposes, the reciprocal of the indexes is shown in Table 5 (see, e.g., Färe, Grosskopf, Lindgren, & Roos, 1992). Hence, a value > 1 represents improvement and a value < 1 represents regress. The annual values were calculated based on samples of firms present in every adjacent 2-year period and the values for the complete sample period were calculated based on a sample of firms that operated in every year.

For Model 1 we find no significant technical change; however, we find significant technical efficiency improvement, which caused TFP to increase when we consider only samples of firms present in every adjacent 2-year period between 2002 and 2013. A similar pattern is observed, when we consider the total sample period: significant technical efficiency improvement overcompensated technical stagnation and led TFP to increase by approximately 4%. Therefore, European life insurers on average enhanced efficiency and consequently, increased TFP, while the best practice frontier did not improve in the industry. Cummins and Rubio-Misas (2006) argue that the costs of adjusting to new environmental conditions (e.g., new regulations) might lead to a slippage in the production frontier, thereby preventing favorable shifts or even causing negative shifts in the production frontier, which they document for the Spanish insurance market in 1989–1998. In addition, Biener et al. (2016) relate significant technical regress and a decline in TFP in the Swiss life insurance sector between 1997 and 2013 to an increasingly challenging business environment of low interest rates and increased competition from other financial service providers, such as banks.

Further country-specific evidence of TFP changes are presented for Austria (+10% for 1992–1999) and Germany (+17.8% for 1991–2006) by Mahlberg and Url (2003, 2010). These growth rates are significantly higher than our estimates but each case represents only the development of one country and has time windows in which the economies were generally in good conditions. The two most recent European cross-country analyses are conducted by Bertoni and Croce (2011) for a sample of German, French, Italian, Spanish, and British life insurers (+6.71% p.a. in 1997–2004) and Vencappa et al. (2013), who document multiple negative annual TFP growth estimates in the life insurance sector in a period with substantial capital market turbulence. Regarding the significant growth documented by Bertoni and Croce (2011), it is important to note that this almost exclusively stems from technical change and the results are heavily influenced by the performance of a relatively small number of mostly Italian and French insurers.

Table 5 shows that in both the pre- and post-crisis periods no technical change occurred and that the significant technical efficiency improvement was the main driver of TFP growth (Model 1). These findings mirror the conclusions drawn from Figure 1: different and harsher business conditions put pressure on European life insurers to increase efficiency.

These findings are robust in the sense that if we control for the business environment (Model 2), we find no technical efficiency improvement over the complete sample period; technical efficiency change is even negative in the post-crisis period. In other words, the differences between Models 1 and 2 must be due to environmental impacts. Without pressure from the environment, management does not seem to be encouraged to enhance efficiency. This again illustrates that European life insurers are under pressure due to the challenging changes in their business environment and that this is the main channel for productivity improvements. Thus, these results again emphasize the importance of decomposing productivity and efficiency changes into environmental and managerial effects.

5 Conclusions

We analyze the impact of environmental conditions on the productivity and efficiency of European life insurance companies using multi-stage DEA. This approach enables us to distinguish environmental changes and changes in management practices. We also identify environmental conditions and firm-specific drivers of efficiency in truncated regression analyses. Our results confirm the significant impact of the business environment (i.e., general economic, capital market, and insurance market conditions) on life insurer efficiency. Furthermore, our study emphasizes the need to control for the business environment in cross-country efficiency studies; otherwise, the efficiency of companies operating under less favorable business conditions is underestimated. Moreover, we show that a difficult business environment probably accounts for the technical stagnation and significant technical efficiency improvement in the European life insurance sector over the sample period. In addition, these results illustrate the consolidation process in the European life insurance market, in which inefficient firms have to leave the market.

These findings have implications for insurance managers, regulators, and policymakers. They show that the life insurance industry is facing increasing pressure and that bad internal performance (underwriting practices and cost management) can no longer be compensated for via a good environmental situation (e.g., high capital market returns). Furthermore, the competitive position of the industry may further decrease and companies may leave or stop considering whether to enter the market. In addition, our analyses reveal that the differences in business conditions across countries harm the efficiency of life insurers that are exposed to relatively unfavorable conditions leading to competitive disadvantages for those companies. Thus, further harmonization of business conditions would help to prevent some marketplaces from becoming less competitive in the internal European market. In addition, differences in business conditions and their efficiency implications should be considered in policymaking, especially when standardized rules are introduced. Furthermore, the results indicate that some life insurers are overutilizing equity capital, a finding that might be important for the appropriate definition of risk-based capital standards by regulators. Overall, the findings help to validate and better understand the determinants of productivity and efficiency in the insurance sector.

Moreover, the analysis presents opportunities for future research in various directions. For example, on the methodological side, other types of efficiency (e.g., revenue efficiency and profit efficiency), other types of adjustments (e.g., conditional mean approach used in stochastic frontier analysis), and other types of relationships (e.g., non-linear link between GDP and efficiency, as indicated by the S-curve; see Enz, 2000) could be analyzed. In addition, one of the methodological limitations of multi-stage DEA could be advanced by altering the assumption that, for example, only the country-specific capital market conditions are relevant for life insurers in one country. In addition, the impact of environmental variables could be analyzed further in an expanded dynamic DEA model (see, e.g., Färe & Grosskopf, 1996; Lu et al., 2014) which could be beneficial to discuss effects over time—for example, the potential capital accumulation over time due to the anticipated implementation of new capital regulations in the EU (Solvency II). Furthermore, the impact of lapse on life insurer efficiency could be researched further if more detailed data become available. Cross-frontier analyses (Biener & Eling, 2012) could be used to further validate how different the business environments are 20 years after the liberalization of the European marketplace. In addition, it could be interesting to analyze the impacts on insurer efficiency in the European market after the United Kingdom exits the EU and to consider specifically the implications of bilateral agreements (e.g., passport rights for insurers) or different regimes (e.g., regulatory requirements) for EU and non-EU insurers.

Regarding the industry and geographical coverage, the European non-life sector has not yet been considered in the context of multi-stage DEA. Furthermore, a comparison of our results with banks and pension funds might be a fruitful avenue for future research. For example, it might be interesting to analyze whether banks and pension funds in Switzerland (Ireland) also profited (suffered) from the relatively good (bad) operating environment. Another relevant direction of study might be to consider whether efficiency in those industries improved due to the difficult business conditions. In addition, adding more immature insurance markets (e.g., Poland and Hungary) would be interesting once the data becomes available, as this would lead to more variation in the dataset. Moreover, as the economic and regulatory developments discussed in this paper are a global phenomenon, it would be interesting to analyze how life insurers outside Europe (North American and Asian markets) handle the increasingly difficult business environment. Lastly, our finding that some life insurers are overutilizing equity capital provides a basis to analyze the sources for the country differences and their development over time—especially in the context of harmonized capital adequacy rules (Solvency II).

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Appendix A

Asset Allocation of European life insurers over time and across countries

Year	Interest-bearing instruments	Other Investments	Real Estate	Shares
2002	60.57%	9.21%	5.84%	24.40%
2003	60.72%	11.01%	4.73%	24.22%
2004	56.47%	14.67%	4.47%	24.38%
2005	53.88%	17.98%	4.24%	23.90%
2006	50.99%	22.46%	4.10%	22.45%
2007	55.65%	19.15%	4.74%	20.46%
2008	56.09%	24.10%	4.67%	15.14%
2009	67.00%	14.31%	4.08%	14.87%
2010	65.54%	15.03%	3.59%	15.85%
2011	66.29%	16.32%	3.69%	13.69%
2012	62.03%	16.93%	3.32%	17.72%
2013	60.97%	16.94%	3.14%	19.16%
Total	59.91%	16.66%	4.13%	19.41%

Notes: The mean asset allocation is calculated based on the OECD Insurance Statistics (edition 2015) database which gives the outstanding investments by direct insurance companies. The investments shares were calculated based on the information for the 14 sample companies. The category interest-bearing instruments comprises bonds issued by public and private sector, loans other than mortgage loans, and mortgage loans.

Country	Interest-bearing instruments	Other Investments	Real Estate	Shares
Austria	55.24%	9.46%	2.34%	32.96%
Belgium	76.94%	9.74%	1.46%	11.86%
Denmark	45.79%	6.96%	1.21%	46.04%
Finland	42.78%	26.78%	4.61%	25.82%
France	73.40%	0.78%	2.96%	22.86%
Germany	67.14%	26.93%	1.95%	3.97%
Ireland	39.13%	55.82%	1.28%	3.78%
Italy	80.18%	13.74%	0.31%	5.77%
Luxembourg	50.77%	24.14%	0.09%	25.00%
Netherlands	62.44%	15.46%	4.08%	18.02%
Norway	66.41%	4.35%	11.99%	17.25%
Sweden	55.46%	7.72%	3.05%	34.45%
Switzerland	67.61%	15.22%	11.28%	5.89%
UK	55.56%	12.38%	5.71%	26.36%
Total	59.85%	16.66%	4.13%	19.41%

Notes: The mean asset allocation is calculated based on the OECD Insurance Statistics (edition 2015) database which gives the outstanding investments by direct insurance companies. The investments shares were calculated based on the information for the 2002–2013 period. The category interest-bearing instruments comprises bonds issued by public and private sector, loans other than mortgage loans, and mortgage loans.

Appendix B

Comparison of traditional, multi-stage, and one-stage DEA models

	Traditional DEA	Multi-stage DEA	One-stage DEA
Country	TE	TE	TE
Austria	0.92	0.87	0.96
Belgium	0.90	0.85	0.91
Denmark	0.97	0.95	0.97
Finland	0.94	0.87	0.97
France	0.90	0.86	0.91
Germany	0.93	0.89	0.94
Ireland	0.83	0.85	0.83
Italy	0.93	0.92	0.92
Luxembourg	0.93	0.90	0.95
Netherlands	0.93	0.90	0.93
Norway	0.97	0.93	0.97
Sweden	0.95	0.94	0.96
Switzerland	0.92	0.83	0.97
United Kingdom	0.83	0.82	0.84
Total Sample	0.91	0.88	0.92

Notes: The efficiency levels in the first and second column represent the results of Model 1 and Model 2, respectively. The efficiency levels in the third column represent the results of a one-stage DEA Model following Cooper et al. (2007). In this model, we use the unadjusted input values and let the interest rate level, inflation, and regulation variables appear as fixed (i.e., non-discretionary) inputs because Table 4 reveals a significant negative relation between these environmental factors and technical efficiency. Correspondingly, we let the stock market performance and competition variables appear as fixed (i.e., non-discretionary) outputs because Table 4 reveals a significant positive relation between these environmental variables and technical efficiency. We did not include the economic maturity and unemployment variable because Table 4 reveals no significant relationship for these environmental factors. On average, the results of the one-stage DEA model are higher than the traditional and multi-stage DEA models which results from that the number of efficient DMUs may only increase because the number of variables included in the model increases (Yang and Pollitt, 2009).

Appendix C

Slack regression results (SFA model)

	Slack1 Labor	Slack 2 Debt	Slack 3 Equity
General economic conditions			
GDP	-0.347***	-0.036***	-0.034***
	(0.024)	(0.009)	(0.009)
UNE	0.027*	-0.017***	-0.020***
	(0.015)	(0.005)	(0.005)
INF	0.808***	-0.002	0.005
	(0.095)	(0.036)	(0.034)
Capital market conditions			
IR	0.012	0.047***	0.048***
	(0.015)	(0.005)	(0.005)
MSCI	-0.272***	-0.058***	-0.060***
	(0.017)	(0.006)	(0.006)
Insurance market conditions			
COMP	0.090***	-0.016**	-0.015**
	(0.018)	(0.007)	(0.007)
SOLV	-0.035***	0.023***	0.024***
	(0.011)	(0.004)	(0.004)
Log likelihood function	-2565.37	4853.34	4778.68
Sigma_v	0.120	0.015	0.015
γ^m	0.005	0.000	0.000
Number of observations	7,149	7,149	7,149

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, based on a two-sided test with a *t*-distribution; the numbers in parentheses are standard errors. The table presents slack regression results based on a SFA slack regression model. The SFA regression equation is specified as follows (see Huang and Eling, 2013):

$$S_{mj} = f^m(Z_j;\beta^m) + v_{mj} + u_{mj}\text{; m=1, 2, ……, M; j=1,2,….., N,}$$

where S_{mj} is the percentage of total input slacks in the usage of input m for DMU j. Z_j is a vector of uncontrollable variables for DMU j. β^m is a vector of coefficients. It is further assumed that v_{mj} (normally distributed with zero mean and variance σ^2_{vm}) reflects statistical noise, and u_{mj} (half-normal distributed with variance σ^2_{um}) reflects managerial inefficiency. Regarding the functional form of f^m, we follow Cooper et al. (2007) and set the environmental variables into logarithms. Note that we need SFA only for the second-stage regression and not for the determination of efficiency scores.

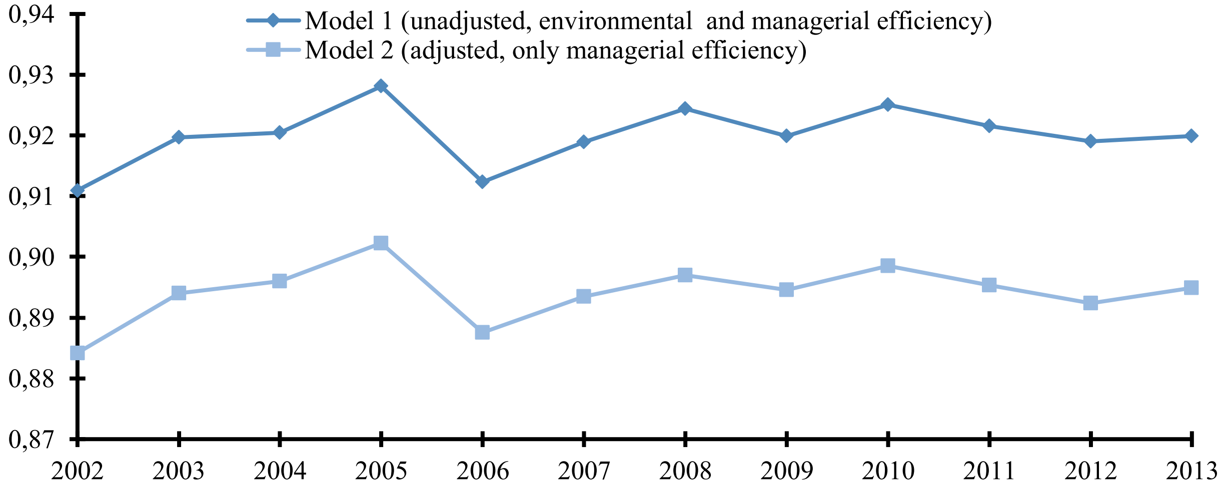
Appendix D
Alternative regression models

	Linear TE	Tobit TE	Logit TE	Probit TE	Loglog TE	Cloglog TE	Linear CE	Tobit CE	Logit CE	Probit CE	Loglog CE	Cloglog CE
Panel A: Regression of environmental conditions												
GDP	0.000	0.000	-0.009	-0.001	-0.011	0.002	0.034***	0.034***	0.147***	0.089***	0.116***	0.090***
	(0.004)	(0.004)	(0.064)	(0.032)	(0.061)	(0.024)	(0.007)	(0.007)	(0.033)	(0.020)	(0.026)	(0.021)
UNE	0.002	0.003	0.006	0.007	0.004	0.007	-0.038***	-0.038***	-0.153***	-0.096***	-0.115***	-0.106***
	(0.003)	(0.003)	(0.037)	(0.019)	(0.035)	(0.014)	(0.005)	(0.005)	(0.019)	(0.012)	(0.014)	(0.013)
INF	-0.035***	-0.035***	-0.617***	-0.273***	-0.604***	-0.177***	0.054***	0.054***	0.225***	0.139***	0.168***	0.151***
	(0.005)	(0.006)	(0.086)	(0.043)	(0.081)	(0.032)	(0.009)	(0.009)	(0.040)	(0.025)	(0.03)	(0.028)
IR	-0.024***	-0.024***	-0.262***	-0.133***	-0.246***	-0.101***	0.036***	0.036***	0.151***	0.094***	0.114***	0.101***
	(0.003)	(0.003)	(0.043)	(0.023)	(0.039)	(0.019)	(0.006)	(0.006)	(0.026)	(0.016)	(0.019)	(0.018)
MSCI	0.013***	0.013***	0.141***	0.072***	0.135***	0.055***	0.075***	0.075***	0.312***	0.194***	0.232***	0.213***
	(0.003)	(0.003)	(0.038)	(0.019)	(0.036)	(0.015)	(0.005)	(0.005)	(0.020)	(0.012)	(0.015)	(0.013)
COMP	0.005**	0.005**	0.116***	0.048***	0.116***	0.028**	-0.022***	-0.022***	-0.090***	-0.056***	-0.064***	-0.063***
	(0.002)	(0.002)	(0.032)	(0.016)	(0.031)	(0.012)	(0.004)	(0.004)	(0.016)	(0.01)	(0.012)	(0.011)
SOLV	-0.004*	-0.004*	-0.028	-0.015	-0.027	-0.012	-0.055***	-0.055***	-0.228***	-0.141***	-0.170***	-0.154***
	(0.002)	(0.002)	(0.031)	(0.015)	(0.03)	(0.011)	(0.004)	(0.004)	(0.016)	(0.010)	(0.011)	(0.011)
Year fixed effects/constant term	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006
Panel B: Regression of firm characteristics Model 1 (unadjusted)												
OWN	-0.021***	-0.021***	-0.283***	-0.14***	-0.268***	-0.102***	-0.053***	-0.053***	-0.230***	-0.141***	-0.176***	-0.147***
	(0.002)	(0.002)	(0.020)	(0.010)	(0.020)	(0.007)	(0.002)	(0.002)	(0.010)	(0.006)	(0.008)	(0.007)
SIZE	0.004**	0.004**	0.045**	0.023**	-0.018	-0.008	0.047***	0.047***	0.197***	0.122***	0.055***	0.031***
	(0.002)	(0.002)	(0.023)	(0.012)	(0.013)	(0.005)	(0.003)	(0.003)	(0.011)	(0.007)	(0.01)	(0.007)
$SOLV_j$	-0.010***	-0.010***	-0.102***	-0.055***	-0.115***	-0.054***	-0.073***	-0.073***	-0.340***	-0.201***	-0.253***	-0.331***
	(0.002)	(0.002)	(0.018)	(0.010)	(0.013)	(0.006)	(0.003)	(0.003)	(0.013)	(0.008)	(0.008)	(0.010)
Year fixed effects/constant term	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006
Panel C: Regression of firm characteristics Model 2 (adjusted)												
OWN	-0.021***	-0.021***	-0.193***	-0.103***	-0.179***	-0.080***	-0.051***	-0.052***	-0.223***	-0.136***	-0.187***	-0.154***
	(0.001)	(0.001)	(0.013)	(0.007)	(0.012)	(0.005)	(0.003)	(0.003)	(0.011)	(0.007)	(0.009)	(0.007)
SIZE	0.005***	0.005**	0.041***	0.022***	-0.009	-0.004	0.057***	0.059***	0.241***	0.149***	0.278***	0.166***
	(0.002)	(0.002)	(0.016)	(0.009)	(0.009)	(0.004)	(0.003)	(0.003)	(0.013)	(0.008)	(0.018)	(0.012)
$SOLV_j$	-0.005***	-0.005**	-0.043***	-0.024***	-0.057***	-0.029***	-0.054***	-0.054***	-0.238***	-0.141***	-0.193***	-0.251***
	(0.002)	(0.002)	(0.014)	(0.008)	(0.011)	(0.005)	(0.003)	(0.003)	(0.016)	(0.01)	(0.011)	(0.012)
Year fixed effects/constant term	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006	7,006

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. TE=technical efficiency, CE=cost efficiency. The dependent variables are truncated at the 99th percentile. The independent variables are mean centered and scaled by their standard deviations. Earlier versions of this paper used the regression algorithm proposed by Simar and Wilson (2007). However, the regression algorithm delivered relatively unstable results when the inverse of the efficiency scores was used (because of the extreme spread in the response variable, as discussed also by Ramalho et al., 2010).

Appendix E

Term efficiencies of dynamic DEA model



Notes: This figure illustrates mean term efficiencies in accordance with the dynamic slack-based measure approach for life insurance contexts proposed by Lu et al. (2014) based on a sample of firms that operated in every year. In this approach, debt and equity capital are treated as carry-overs between two consecutive periods. The figure illustrates that (term) efficiency also increased over the sample period in the dynamic DEA approach. The overall efficiency during the sample period (see Tone and Tsutsui, 2009) is 0.92 for Model 1 and 0.89 for Model 2. Overall, the efficiency levels estimated by the dynamic approach appear on average slightly higher and more stable over time compared to the traditional DEA model which is in line with Lu et al. (2014).

Appendix F

Sample (stocks/mutuals/total) by country and year

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Austria	3/0/3	3/0/3	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	2/0/2	26/0/26
Belgium	12/3/15	13/3/16	16/3/19	14/2/16	11/1/12	11/1/12	7/1/8	10/1/11	10/1/11	10/1/11	10/1/11	9/1/10	133/19/152
Denmark	19/26/45	19/28/47	18/26/44	15/26/41	11/19/30	16/24/40	14/15/29	18/24/42	17/25/42	18/25/43	14/13/27	11/13/24	190/264/454
Finland	24/11/35	24/11/35	23/11/34	20/11/31	17/11/28	19/11/30	10/10/20	17/11/28	17/11/28	17/11/28	11/6/17	11/6/17	210/121/331
France	48/8/56	50/9/59	46/7/53	45/9/54	36/5/41	46/6/52	37/3/40	45/3/48	45/2/47	36/3/39	36/3/39	36/2/38	506/60/566
Germany	137/62/199	143/66/209	149/63/212	145/63/208	132/60/192	146/86/232	139/86/225	147/99/246	147/108/255	144/111/255	142/109/251	140/108/248	1,711/1,021/2,732
Ireland	35/0/35	40/0/40	40/0/40	41/0/41	34/0/34	42/0/42	21/0/21	38/0/38	35/0/35	37/0/37	29/0/29	27/0/27	419/0/419
Italy	48/0/48	52/0/52	46/0/46	44/0/44	37/0/37	47/0/47	33/0/33	41/0/41	44/0/44	41/0/41	40/0/40	39/0/39	512/0/512
Luxembourg	9/0/9	10/0/10	10/0/10	8/0/8	7/0/7	11/0/11	6/0/6	6/0/6	6/0/6	7/0/7	7/0/7	8/0/8	95/0/95
Netherlands	46/8/54	54/8/62	51/6/57	49/5/54	30/4/34	33/4/37	23/4/27	27/4/31	24/4/28	22/4/26	12/4/16	13/3/16	384/58/442
Norway	7/1/8	7/1/8	6/1/7	6/1/7	7/1/8	9/1/10	8/1/9	12/1/13	13/1/14	13/1/14	9/1/10	9/1/10	106/12/118
Sweden	14/6/20	17/5/22	17/5/22	17/6/23	14/3/17	24/4/28	19/5/24	14/0/14	24/5/29	18/5/23	16/2/18	12/0/12	206/46/252
Switzerland	20/2/22	20/2/22	19/1/20	16/1/17	17/1/18	20/2/22	12/1/13	19/2/21	17/2/19	17/2/19	21/2/23	19/3/22	217/21/238
United Kingdom	80/1/81	106/2/108	103/4/107	96/4/100	63/1/64	66/0/66	34/0/34	58/1/59	56/1/57	48/1/49	45/1/46	41/0/41	796/16/812
Total	502/128/630	558/135/693	546/127/673	518/128/646	418/106/524	492/139/631	365/126/491	454/146/600	457/160/617	430/164/594	394/142/536	377/137/514	5,511/1,638/7,149

Appendix G

PTE, AE, and SE efficiency levels

	Model 1			Model 2			Delta (Model 2-Model 1)		
Country	PTE	AE	SE	PTE	AE	SE	PTE	AE	SE
Austria	0.92	0.64	1.00	0.87	0.66	1.00	-0.05***	0.02	0.00
Belgium	0.90	0.62	1.00	0.85	0.64	1.00	-0.05***	0.02	0.00
Denmark	0.96	0.74	1.00	0.93	0.74	1.00	-0.03***	0.00	0.00***
Finland	0.94	0.71	1.00	0.87	0.73	1.00	-0.07***	0.02**	0.00
France	0.90	0.70	0.99	0.86	0.72	1.00	-0.04***	0.02***	0.01
Germany	0.93	0.61	1.00	0.89	0.63	1.00	-0.04***	0.02***	0.00*
Ireland	0.83	0.50	0.98	0.83	0.60	1.00	0.00	0.10***	0.02***
Italy	0.92	0.60	1.00	0.89	0.62	1.00	-0.03***	0.02***	0.00***
Luxembourg	0.91	0.69	1.00	0.85	0.66	1.00	-0.06**	-0.03	0.00***
Netherlands	0.92	0.58	1.00	0.88	0.60	1.00	-0.04***	0.02	0.00***
Norway	0.96	0.73	1.00	0.93	0.75	1.00	-0.03***	0.02*	0.00
Sweden	0.94	0.48	1.00	0.91	0.49	1.00	-0.03***	0.01	0.00**
Switzerland	0.92	0.53	0.98	0.85	0.59	0.97	-0.07***	0.06***	-0.01**
United Kingdom	0.83	0.68	0.99	0.82	0.71	1.00	-0.01	0.03***	0.01***
Total Sample	0.91	0.63	0.99	0.88	0.65	1.00	-0.03***	0.02***	0.01***

Notes: Model 1 PTE levels are on average (0.91) relatively equal to the average TE level (0.91) for the total sample. This is mirrored in an average SE score of 0.99. Thus, European life insurers could only improve their size of operations by 1% to become fully scale efficient. In Model 2, the average PTE (0.88) is also relatively equal to the average TE (0.88). Average AE scores are slightly higher in Model 2 than in Model 1. As it is the case for CE, there is much room for further improvement of AE. Test of significance is based on a two sample t-test (two-tailed) with the null hypothesis that the true difference in means is equal to 0. ***, **, and * represent significant differences in means at the 1%, 5%, and 10% levels, respectively.

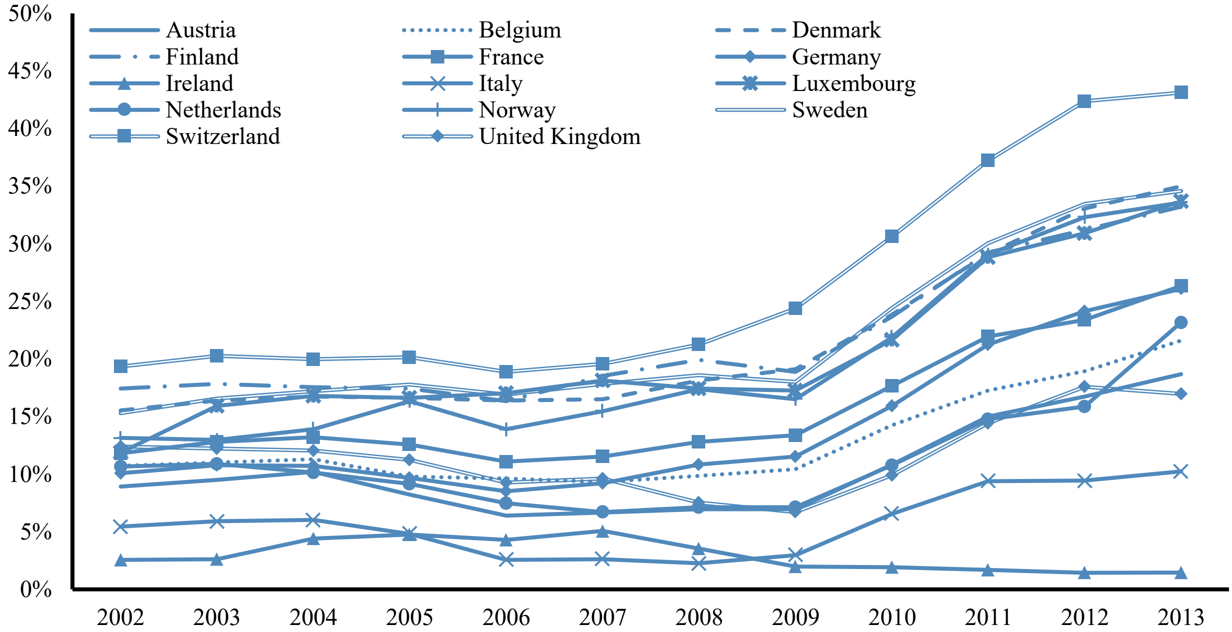
Appendix H

Summary statistics of adjusted input data

	Input 1 Labor (in 1,000s)					Input 2 Debt (in bn USD)					Input 3 Equity capital (in bn USD)				
Country	Mean	STD	Min	Max	Adjust-ment	Mean	STD	Min	Max	Adjust-ment	Mean	STD	Min	Max	Adjust-ment
Austria	1.05	1.08	0.06	3.60	15%	2.40	2.38	0.16	5.76	8%	0.06	0.05	0.02	0.18	8%
Belgium	0.27	0.34	0.00	1.49	22%	0.83	2.39	0.01	19.23	7%	0.04	0.10	0.00	0.70	8%
Denmark	0.15	0.27	0.00	2.16	47%	3.96	5.50	0.00	33.79	7%	0.44	0.53	0.00	3.01	8%
Finland	1.02	0.87	0.02	3.05	40%	7.72	9.80	0.02	41.06	11%	0.62	0.98	0.00	5.04	12%
France	2.09	6.64	0.00	135.16	30%	8.71	13.85	0.00	93.70	8%	0.39	0.58	0.00	4.50	8%
Germany	1.93	4.49	0.00	73.93	28%	5.91	15.01	0.00	217.52	7%	0.11	0.20	0.00	2.34	8%
Ireland	2.09	2.82	0.00	19.97	7%	4.25	10.26	0.00	97.14	1%	0.22	0.40	0.00	3.30	1%
Italy	6.29	12.13	0.00	135.04	7%	5.97	9.24	0.01	67.88	5%	0.25	0.44	0.01	3.51	5%
Luxembourg	1.02	1.59	0.09	10.38	41%	3.55	4.96	0.36	28.66	10%	0.06	0.05	0.01	0.24	10%
Netherlands	4.43	12.13	0.00	91.51	16%	9.28	18.84	0.00	82.85	7%	0.82	1.73	0.00	10.82	8%
Norway	3.01	3.35	0.00	15.05	46%	15.02	15.70	0.01	54.83	8%	1.01	0.99	0.00	3.59	8%
Sweden	3.17	6.01	0.00	44.03	50%	10.80	13.38	0.00	69.45	7%	4.47	7.50	0.00	28.96	7%
Switzerland	2.59	4.84	0.00	40.66	56%	16.17	32.77	0.00	198.20	12%	0.69	1.67	0.00	12.44	12%
UK	8.67	24.41	0.00	301.46	26%	20.42	43.50	0.00	416.30	4%	0.95	1.77	0.00	14.01	4%
Total sample	3.06	1.08	0.00	301.46	28%	8.37	20.71	0.00	416.30	7%	0.52	1.85	0.00	28.96	7%

Appendix I

Average Input Adjustments per year and country



Appendix J

Change in average CE levels if the interest rate levels increase

$SOLV_j$ Deciles	CE_1 (observed prices)	CE_2 (IR+1 %)	Delta (CE2-CE1)
Q1	0.7259	0.7505	3.40%
Q2	0.6900	0.7186	4.15%
Q3	0.6017	0.6343	5.41%
Q4	0.6251	0.6565	5.03%
Q5	0.5979	0.6304	5.43%
Q6	0.6077	0.6396	5.24%
Q7	0.5808	0.6140	5.72%
Q8	0.5799	0.6195	6.84%
Q9	0.3942	0.4289	8.82%
Q10	0.3728	0.4184	12.23%
Arithmetic mean	0.5773	0.6108	5.80%

Notes: For this example, we estimate CE in our sample for the year 2002 based on observed input prices (CE_1). Next, we artificially increase the interest rate levels, which is the price of the input debt (x3), by 1% (keeping all other input prices unchanged) across all countries and re-estimated CE (CE_2). We report the CE scores as mean values separately for $SOLV_j$ (firm-specific equity to total assets) deciles and for the total sample. Appendix J reveals that insurers with lower $SOLV_j$ ratios (accordingly classified in lower deciles) are on average more cost efficient. Furthermore, if the interest rate level increases, CE on average increases. Moreover, the efficiency gains seem to be higher for higher $SOLV_j$ levels. Because equity is generally more expensive than debt, more solvent firms appear to be less cost efficient at first glance. However, if the interest rate level increases, the difference between equity price and debt price becomes less relevant.

Appendix K

Partition test: stock market performance effects in countries with relatively high (Subsample A) and relatively low stock market activity (Subsample B).

	Subsample A		Subsample B	
	TE	CE	TE	CE
General economic conditions				
GDP	0.000	0.028*	-0.019**	0.005
	(0.008)	(0.015)	(0.008)	(0.056)
UNE	0.005*	-0.036***	-0.047***	-0.066***
	(0.003)	(0.005)	(0.013)	(0.018)
INF	-0.019***	0.059***	-0.074***	0.011
	(0.007)	(0.013)	(0.025)	(0.036)
Capital market conditions				
IR	-0.052***	0.079***	0.004	0.061***
	(0.007)	(0.014)	(0.011)	(0.016)
MSCI	0.020***	0.097***	0.019	0.010
	(0.006)	(0.012)	(0.013)	(0.019)
Insurance market conditions				
COMP	-0.003	-0.035***	0.017*	0.056***
	(0.004)	(0.008)	(0.010)	(0.014)
SOLV	0.001	-0.069***	-0.035***	-0.101***
	(0.003)	(0.005)	(0.012)	(0.018)
Year fixed effects/constant term	YES	YES	YES	YES
Observations	5,926	5,926	1,080	1,080

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. TE=technical efficiency, CE=cost efficiency. We use Farrell efficiency scores as dependent variables and apply a truncated regression model with left truncation at 0 and right truncation at 1. The dependent variables are truncated at the 99th percentile. The independent variables are mean centered and scaled by their standard deviations. The sample is split into two sub-samples: sample A constitutes countries with stock exchanges that have relatively high market capitalization (i.e., Belgium, Denmark, Finland, France, Germany, the Netherlands, Sweden, Switzerland, and the United Kingdom) and sample B constitutes countries with stock exchanges that have relatively low market capitalization (i.e., Austria, Luxembourg, Ireland, Italy, and Norway).

Appendix L

Partition test—regulatory effects before and after 2007

	Subsample (2002–2006)		Subsample (2007–2013)	
	TE	CE	TE	CE
General economic conditions				
GDP	0.030**	0.123***	-0.006	0.033***
	(0.012)	(0.019)	(0.004)	(0.008)
UNE	0.020***	-0.003	-0.017***	-0.025**
	(0.012)	(0.007)	(0.005)	(0.010)
INF	-0.043*	0.082**	-0.031***	0.077***
	(0.022)	(0.036)	(0.005)	(0.010)
Capital market conditions				
IR	-0.011	0.114***	0.001	0.037***
	(0.010)	(0.016)	(0.004)	(0.008)
MSCI	0.006	0.065***	0.027***	0.119***
	(0.005)	(0.008)	(0.004)	(0.008)
Insurance market conditions				
COMP	0.017***	0.000	-0.004	-0.056***
	(0.004)	(0.007)	(0.003)	(0.006)
SOLV	0.014***	-0.041***	-0.015***	-0.081***
	(0.004)	(0.007)	(0.002)	(0.005)
Year fixed effects/constant term	YES	YES	YES	YES
Observations	3,113	3,113	3,893	3,893

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. TE=technical efficiency, CE=cost efficiency. We use Farrell efficiency scores as dependent variables and apply a truncated regression model with left truncation at 0 and right truncation at 1. The dependent variables are truncated at the 99th percentile. The independent variables are mean centered and scaled by their standard deviations. The sample is split into two sub-samples (before and after 2007—i.e., the launching of the formal legislative process) to analyze the anticipated introduction of Solvency II.

Appendix M

Productivity and its sources (technical change and technical efficiency change) over time

Period	2002/2003			2003/2004			2004/2005			2005/2006			2006/2007			2007/2008			2008/2009			2009/2010			2010/2011			2011/2012			2012/2013		
Model 1	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP
Austria	1.00	1.03	1.03	1.00	0.97	0.97	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.02	1.00	0.99	0.99
Belgium	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	0.99	1.03	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
Denmark	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.01	1.00	1.00	1.02	1.02	1.00	0.99	0.99	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00
Finland	1.01	1.00	1.01	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
France	0.99	1.03	1.02	1.00	1.00	1.00	1.00	1.03	1.04	1.00	1.02	1.01	1.04	0.99	1.01	1.00	0.99	0.99	1.00	0.99	0.99	1.00	1.01	1.01	1.00	0.99	0.99	1.00	0.99	0.99	1.00	1.00	1.00
Germany	0.99	1.00	0.99	1.00	1.02	1.02	1.00	1.02	1.02	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.02	1.00	1.02	1.00	1.00	1.00	1.00	1.00	1.00
Ireland	1.00	1.06	1.06	1.00	0.98	0.98	1.00	1.04	1.04	1.00	1.00	1.00	1.00	1.01	1.01	1.00	0.95	0.95	1.00	1.35	1.35	1.00	1.03	1.03	1.00	0.97	0.97	1.00	0.99	0.99	1.00	0.99	0.99
Italy	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.99	1.00	1.01	1.01	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Luxembourg	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.00	0.98	0.98	1.00	0.98	0.98	1.00	0.89	0.89	1.00	0.96	0.96	1.00	1.07	1.07	1.00	1.04	1.04	1.00	1.01	1.01
Netherlands	0.99	1.02	1.01	1.00	1.02	1.02	1.00	1.01	1.01	0.99	1.01	1.01	1.00	1.00	1.00	1.01	0.99	1.01	1.00	1.01	1.01	1.00	1.02	1.01	1.00	1.00	1.00	0.99	1.01	1.00	0.99	1.00	0.99
Norway	1.00	1.01	1.01	1.00	1.02	1.02	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.01	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sweden	1.00	1.01	1.01	1.00	0.99	0.99	1.01	1.02	1.03	1.00	1.01	1.01	1.01	1.00	1.01	0.97	1.14	1.10	0.96	1.01	0.97	0.97	0.97	0.94	1.00	0.98	0.98	1.00	0.99	0.99	0.99	0.99	0.98
Switzerland	1.00	1.01	1.01	1.00	1.00	1.00	1.01	1.01	1.02	0.99	0.97	0.97	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00
United Kingdom	1.00	1.01	1.01	1.00	1.01	1.01	1.00	1.02	1.02	1.00	1.00	0.99	1.00	1.05	1.05	1.00	1.04	1.04	1.00	1.01	1.01	1.00	1.00	1.00	1.01	1.00	1.01	1.00	1.01	1.01	1.00	1.01	1.00
Total Sample	0.99	1.01	1.00	1.00	1.01	1.01	1.00	1.02	1.02	1.00	1.01	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.02	1.02	1.00	1.01	1.00	1.01	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.00
Model 2	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP	TC	TEC	TFP
Austria	1.00	0.97	0.97	1.00	1.03	1.03	1.00	0.97	0.97	1.00	0.99	0.99	1.00	0.98	0.98	1.00	1.01	1.01	1.00	1.00	0.99	1.00	1.02	1.02	1.00	1.02	1.02	1.00	0.98	0.98	1.00	1.01	1.01
Belgium	1.00	0.99	0.99	1.00	1.02	1.02	1.00	0.98	0.98	1.00	0.99	0.99	1.00	0.99	0.99	1.01	1.01	1.02	0.99	1.01	1.00	1.01	0.99	1.00	1.01	1.02	1.02	1.00	1.01	1.00	1.02	0.96	0.98
Denmark	1.00	1.02	1.01	0.99	0.99	0.98	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.98	0.98	1.02	1.02	1.04	1.00	1.00	1.00	1.01	1.01	1.02	1.04	1.00	1.03	1.00	1.01	1.01	1.00	0.98	0.97
Finland	0.99	0.99	0.98	1.00	0.99	0.99	1.00	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.03	0.99	1.01	1.00	1.01	1.01	1.02	1.01	1.02	1.03	1.00	1.01	1.01	1.01	0.97	0.98
France	1.01	0.98	0.99	1.00	1.00	1.00	0.99	0.98	0.97	1.00	0.99	0.99	0.98	1.01	0.98	1.01	1.01	1.02	0.99	1.07	1.06	1.01	1.02	1.02	1.01	1.03	1.03	1.00	1.01	1.00	1.01	0.99	1.00
Germany	1.03	1.01	1.04	1.01	0.98	0.99	1.00	0.98	0.98	1.00	0.98	0.98	1.00	0.99	0.98	1.01	1.01	1.02	0.99	1.01	1.01	1.02	1.02	1.04	1.01	1.02	1.03	1.00	1.01	1.01	1.01	0.97	0.98
Ireland	1.00	0.99	0.99	1.00	1.03	1.03	1.00	0.99	0.99	1.00	1.05	1.05	1.00	1.00	1.00	1.01	1.16	1.17	0.99	0.94	0.93	1.01	0.97	0.98	1.01	1.07	1.08	1.00	1.01	1.00	1.00	1.01	1.01
Italy	1.00	0.99	0.99	1.00	0.99	0.99	1.00	0.99	0.99	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.01	1.01	1.00	0.99	0.99	1.00	1.02	1.02	1.00	1.03	1.03	1.00	0.98	0.98	1.00	0.99	0.99
Luxembourg	1.00	1.00	1.00	1.00	1.01	1.01	0.99	1.00	0.99	1.00	0.99	0.98	1.00	1.01	1.01	1.00	1.03	1.03	0.99	1.29	1.28	1.00	1.09	1.09	1.01	0.98	0.99	1.00	0.97	0.96	1.01	0.96	0.97
Netherlands	1.01	0.99	0.99	1.00	0.98	0.98	0.99	0.99	0.98	1.01	0.98	0.99	1.00	1.00	1.00	1.00	1.02	1.01	1.00	1.00	0.99	1.01	0.99	1.01	1.01	1.03	1.03	1.01	1.00	1.01	1.01	0.98	0.99
Norway	1.00	1.00	0.99	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.99	0.98	1.00	1.00	1.00	1.01	1.00	1.01	1.00	1.00	0.99	1.00	1.02	1.03	1.01	1.04	1.05	1.00	1.01	1.01	1.01	0.97	0.97
Sweden	1.00	0.99	0.99	1.00	1.00	1.00	0.99	0.98	0.97	0.99	0.99	0.98	0.99	0.99	0.98	1.11	0.98	1.10	1.07	1.00	1.07	1.07	1.04	1.11	1.01	1.06	1.07	1.00	1.02	1.02	1.01	0.97	0.98
Switzerland	1.00	1.00	1.00	1.00	0.99	0.99	0.99	1.01	1.00	1.01	1.05	1.07	1.01	1.00	1.01	1.00	0.99	1.00	1.00	1.02	1.01	1.01	1.03	1.03	1.01	1.02	1.03	1.00	1.01	1.01	1.01	0.96	0.97
United Kingdom	1.00	0.99	0.99	0.99	0.99	0.98	1.00	0.98	0.97	1.00	1.01	1.01	1.00	0.97	0.97	1.01	0.98	0.99	0.99	1.02	1.02	1.01	1.02	1.03	1.00	1.04	1.05	1.00	1.01	1.01	1.01	0.95	0.96
Total Sample	1.01	1.00	1.01	1.00	0.99	0.99	1.00	0.98	0.98	1.00	0.99	1.00	1.00	0.99	0.99	1.01	1.01	1.03	1.00	1.01	1.01	1.01	1.01	1.03	1.01	1.02	1.03	1.00	1.01	1.01	1.01	0.98	0.98

Notes: For illustrative purposes, the reciprocal of the indexes is shown (see, e.g., Färe et al., 1992). Hence, a value > 1 represents improvement and a value < 1 represents regress. TC=technical change, TEC=technical efficiency change, TFP=total factor productivity.

Part II

Get the Balance Right: A Simultaneous Equation Model to Analyze Growth, Profitability, and Safety

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Abstract

We develop a simultaneous equation model to test the reciprocal relationships among growth, profitability, and safety. Analyzing 1,988 European insurance companies over eleven years, we find that moderate firm growth increases profitability and reduces firm risk; however, extremely high growth reduces profitability and increases risk. In addition, we document that less profitable companies are risk-seeking, a result in line with prospect theory. Our longitudinal an-alyses illustrate that firms initially prioritizing profitability over growth are more likely to reach the ideal state of "profitable growth".

Keywords: Firm performance · Simultaneous equation model · Risk taking · Profitable growth · Strategic management

JEL classification: C33 · C36 · G22 · L21

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1 Introduction

Growth, profitability, and safety are three common business goals. However, goal conflicts constrain the maximization of all three dimensions at the same time. Thus, managers prioritize some goals at the expense of others. In this paper, we analyze the interdependencies among growth, profitability, and safety in the context of the insurance industry, in which the management of the three goals is of utmost importance and draws much managerial attention.[1]

The 2014 annual reports of the 15 largest European insurance companies reveal that 11 of them denote “profitable growth” as one of the main strategic goals. This suggests that many insurers are looking for a balance between profitability and growth. The prioritization of strategic goals also depends on the state of the market and institutional features.[2] In line with life cycle considerations, many organizations in emerging markets focus on growth (Berry-Stölzle, Hoyt, & Wende, 2010), while profitability is often more important in mature markets. During economic crises, risks rise and managing safety might have a higher priority, while profitability and growth become more dominant in booming times. An analysis of the relationships among the three strategic goals, their determining factors, and their development over time is useful for firm management to find the right balance between these three dimensions. Moreover, the analysis is helpful for the performance assessments of other stakeholders, especially that of analysts, investors, and regulators. The extant studies in financial services have either focused on two of the three strategic goals and have not simultaneously accounted for all three interdependencies among growth, profitability, and safety (risk). With respect to the insurance industry, Hardwick and Adams (2002) examine the impact of profitability on organic growth in the United Kingdom (UK) life insurance sector. Leverty and Grace (2010) analyze the impact of premium growth on profitability in the United States (US) property-liability market and also control for the capital-to-assets ratio, a frequently considered risk measure. However, they do not explicitly analyze the interactions among all three goals.

1 Compared to manufacturing, safety is particularly important in (banking and) insurance, due to regulatory requirements, and because customers are sensitive to firm risk. Unlike most other industries, firm risk determines product quality (Eling & Schmit, 2012). Growth is important, as it might help to improve risk diversification. However, growth might also deteriorate profitability and safety while loosening the underwriting discipline (D’Arcy & Gorvett, 2004; Barth & Eckles, 2009). The latter point is similar to granting loans in banking. Thus, we believe that our results are not only relevant for insurance companies, but also for other financial services.

2 Among such institutional features are the degree of regulation, the organizational form, and the structure of employee incentives. In highly regulated industries (e.g., financial services), the trade-off between risk and returns is heavily shaped by regulations. Stock companies typically focus more on profitability than mutual firms, because the main goal of a mutual firm is to fulfill the demand of its members (Martínez, Albarrán, & Camino, 2001; Erhemjamts & Leverty, 2010); this is usually interpreted as a growth target. The compensation and incentive structure of the sales force and management also steers the focus of the organization among growth, profitability, and safety.

Fields, Gupta, and Prakash (2012) investigate the impact of growth and risk taking on underwriting profitability in a global sample of publicly traded insurers. Moreover, they study the impact of growth and profitability on risk taking. Fok et al. (1997) analyze the impact of growth and risk on profitability, as well as the impact of growth on risk in the U.S. property-casualty insurance sector.[3] Although the extant literature implicitly suggests that the relationships among growth, profitability, and safety (risk) are reciprocal, none of these studies simultaneously analyzes all three interdependencies. This literature gap may be due to the endogenous nature of the strategic goals, which challenges the statistical modeling and inferences. To our knowledge, this study is the first to simultaneously analyze the interdependencies among growth, profitability, and safety in the business and finance research. In this context, we also test for non-linear relationships to better understand potential goal conflicts. We contribute to the research on general firm performance (see, e.g., Browne, Carson, & Hoyt, 2001; D'Arcy & Gorvett, 2004; Barth & Eckles, 2009; Casu et al., 2009). In particular, our study extends Goddard et al.'s (2004) analysis of the two-directional links between growth and profitability. We follow Mankaï and Belgacem (2016) and develop a simultaneous equation model (SEM) to address potential endogeneity and capture the interactions of the three strategic goals, while accounting for firm characteristics and market conditions.[4]

Our sample consists of 1,988 life and non-life insurance companies from 16 European countries during the 2002–2013 period (9,298 firm-year observations). We focus on the European market, because of its relative homogeneity in terms of economic development and because its maturity leads to comparable challenges in managing the triangle of growth, profitability, and safety.[5] Our analyses are also relevant for other financial services sectors, with comparable management challenges (e.g., banking with

[3] With respect to the banking industry, García-Herrero, Gavilá, and Santabárbara (2009) analyze the impact of loan growth on bank profitability. Delis and Kouretas (2011) analyze the impact of bank profitability on its risk taking. Goddard, Molyneux, and Wilson (2004) analyze the two-directional link between growth and profitability in European banking.

[4] A SEM is especially suitable for two reasons: First, it allows us to explicitly consider the reciprocal nature of the three strategic goals by fully modelling the interactions among growth, profitability, and safety (risk). Second, it is the only reliable way to make statistical inferences about the impact of any of these dimensions on the other two dimensions, because it holds the reverse impacts constant. Not controlling for the reverse impacts may yield biased and inconsistent results (Wooldridge, 2010). Studies from other fields that analyze the reciprocal relationships between multiple performance dimensions include Schendel and Patton (1978; profitability, market share, and efficiency), Oviatt and Bauerschmidt (1991; risk and return), and Miller and Leiblein (1996; risk and return). SEM's are widely used in the financial services research (see, e.g., Magri, 2010).

[5] The 1994 deregulation of the financial services industry and challenges (e.g., internationalization, low interest rates) imply significant profitability pressure for European financial service firms. For example, Bikker and Van Leuvensteijn (2008) emphasize the shrinking profit margins in the Dutch life insurance sector. In addition, many European financial service firms continuously seek higher growth opportunities abroad. Schoenmaker and Sass (2016) document the increasing levels of the cross-border activities of European insurers since 2000. Finally, the European financial service sector is highly regulated, and thus, companies are required to ensure high safety levels (Eling, Schmeiser, & Schmit, 2007).

respect to regulation and credit discipline; Dell'Ariccia, Igan, & Laeven, 2012)[6] or other markets outside Europe that have similar management considerations, such as the US.

Our findings reveal that the impact of firm growth on profitability and safety is two-fold: moderate growth improves profitability and decreases risk, while extremely high growth reduces profitability and increases risk. These results underline the importance of underwriting discipline (D'Arcy & Gorvett, 2004). Furthermore, extremely high levels of risk are not rewarded with corresponding returns: beyond a certain threshold, the positive risk-profitability relationship diminishes and a further increase of risk reduces profitability, as Bowman (1982) discussed. In addition, we find evidence that insurers with relatively low profitability seek higher risk, as predicted by prospect theory (Jegers, 1991).

We also analyze the interactions among growth, profitability, and safety over time following Davidsson, Steffens, and Fitzsimmons (2009). This analysis reveals that firms that initially prioritize profitability over growth are more likely to reach the ideal state of profitable growth. Moreover, companies which focus on profitability at the expense of current safety are more likely to reach high safety levels in the future. This result emphasizes that superior profitability reflects competitive advantage, which secures not only high growth, but also high and stable economic rents (Davidsson et al., 2009). The analysis also demonstrates that insurers that initially focus on safety are more likely to achieve above average growth, as policyholders tend to choose insurers with high safety levels (Eling & Schmit, 2012) and safe insurers might be able to charge higher premiums. Thus, firms prioritizing profitability and safety over growth are more likely to reach profitable growth with safe operations, than firms that prioritize growth over profitability and safety. Our findings underline the goal conflicts among growth, profitability, and safety and emphasize that the three dimensions need to be jointly considered in a multi-period context to evaluate firm performance.

The remainder of the paper is organized as follows. In the following section, we discuss the theoretical background and develop our hypotheses. Next, we introduce the measures, sample, and our methodology. Then, we present the empirical results together with several robustness tests. Finally, we conclude.

2 Theoretical background and hypothesis development

Like Goddard et al. (2004), we bring classical and behavioral theories together to develop our hypotheses. The relationships among growth, profitability, and safety are formalized in three pairs of hypotheses (see Table 1 for an overview of the hypotheses

[6] This paper is also linked to the context of market discipline in banking (Chen & Hasan, 2011), insurance (Epermanis & Harrington, 2006), and other industries (Ramezani, Soenen, & Jung, 2002), which, among other aspects, considers the risk and return implications of extremely high growth rates.

and Appendix A for the reviewed literature) that we discuss below together with existing empirical results.[7] Representing the reciprocal nature of these relationships, each pair of hypotheses presents two impact directions. For example, we hypothesize the impact of growth on profitability as an inverted-U shape (H1a), while the impact of profitability on growth exhibits a U-shape (H1b).

Table 1 Hypotheses

Relationship	Main arguments
Growth and profitability	
H1a: The impact of firm growth on profitability is non-linear (inverted U-shape).	Scale economies vs. complexity and agency theory (moral hazard, adverse selection, aging phenomenon)
H1b: The impact of firm profitability on growth is non-linear (U-shape).	Expansion in response to reduced profit margins vs. additional internal and external financial resources to grow, efficient structure hypothesis
Safety (risk) and profitability	
H2a: The impact of firm risk on profitability is non-linear (inverted U-shape).	CAPM vs. insolvency risk decreases demand, price, and thus profitability
H2b: The impact of firm profitability on risk is non-linear (U-shape).	Risk-seeking (prospect theory) vs. risk-averse management (CAPM)
Growth and safety (risk)	
H3a: The impact of firm growth on risk is non-linear (U-shape).	Risk diversification vs. loose underwriting discipline increases underwriting and insolvency risks
H3b: The impact of firm risk on growth is non-linear (inverted U-shape).	Take risk to grow vs. insolvency risk decreases the demand

Growth helps firms establish a stronger market position (e.g., through scale economies), and thus, increases profitability (Davidsson et al., 2009). Scale economies are important in insurance not only because of fixed costs degeneration, but also because the risk pooling works better the bigger the pool is, yielding a second source of scale economies (Cummins & Rubio-Misas, 2006). Yuengert (1993) documents that larger life insurers have superior cost efficiency, which consequently improves profitability (Greene & Segal, 2004). Furthermore, moderate growth driven by increasing price levels reduces

[7] The primary intention of this paper is not to write down a comprehensive model considering all interactions among growth, profitability, and safety; rather, we want to empirically test these relationships. In fact, the theories to derive our hypotheses have different origins. A unified theoretical framework does, to our knowledge, not exist; hence, developing such a framework goes beyond the scope of this paper. We refer to the theoretical models presented in the literature to formalize the relationships, including the Capital Asset Pricing Model (CAPM), prospect theory, and agency theory. Thus, we follow the conceptual approach of Goddard et al. (2004) to bring different sets of theory together and test them empirically.

the loss ratio, on average, thereby yielding a positive impact on profitability (Barth & Eckles, 2009).

However, extremely high growth might also be harmful to profitability. Agency theory suggests that management may seek growth as a primary goal by sacrificing profitability to meet their personal ambitions and excessive perquisite consumption (Eisenhardt, 1989). Such moral hazard behavior by management may lead to unintended changes in capital decisions (Mankaï & Belgacem, 2016), indirectly affecting profitability. In addition, high growth increases the complexity of organizations (Nicholls-Nixon, 2005), leading to rising costs and reduced profitability (Williamson, 1966). Furthermore, Fuller and Jensen (2002) claim that management may respond to short-term growth pressure from outside the firm with actions that cause damage in the long run. Excessive inorganic growth strategies bearing unpredicted and inflating costs provide one example.

D'Arcy and Gorvett (2004) suggest that high growth of insurers may only result from pricing tactics that reduce profit margins. Charging prices below the technical price in the competition for customers causes profitability reductions, since claim expenditures and other expenses, *ceteris paribus*, remain unchanged (Jia & Wu, 2017). Similarly, loose underwriting discipline, as a growth strategy, may not only boost sales, but also attract unprofitable risks. As a consequence, risks that would not be accepted when the underwriting standards were higher enter the insurance portfolio (Eling & Schmit, 2012). Furthermore, new and unfamiliar business often generates losses in excess of premiums in the first years (i.e., the so-called aging phenomenon (D'Arcy & Gorvett, 2004)), meaning that the profitability of rapidly growing firms may decline. In many cases, the loss ratio decreases as books of businesses go through renewal cycles because, for example, initial lack of information in the underwriting are remedied (Kunreuther & Pauly, 1985; Nilssen, 2000).

The foregoing arguments indicate that moderate growth drives profits up to a certain threshold, while excessive growth may be harmful to profits. In other words, both extremely low (negative) and high firm growth are potentially harmful to profitability. This relationship is empirically documented in Ramezani et al. (2002), with a sample of U.S. companies from various industries. Thus, our first hypothesis is:

H1a: The impact of firm growth on profitability is non-linear (inverted U-shape).

The growth ambitions of a firm may depend on the current market profitability (Andersen & Kheam, 1998). If profit margins are tight, firms may need to diversify to seek growth opportunities. These arguments suggest a negative impact of profitability on growth at low levels of profitability. On the other hand, good firm profitability may motivate business expansion and enable the management to pursue growth opportunities with more internal[8] and external financial resources (Whittington, 1980). Davidsson et al. (2009) argue that high profitability reflects competitive advantages of the firm; thus, also helping it to achieve growth.

The so-called efficient structure hypothesis also explains the profitability impact on growth. More efficient insurers gain market shares through consolidation or organic growth (Choi & Weiss, 2005; Weiss & Choi, 2008), because they can charge lower prices without sacrificing profitability (Biener, Eling, & Jia, 2017). For these reasons, high firm profitability should have a positive impact on growth. The existing empirical evidence is ambiguous. Hardwick and Adams (2002) cannot confirm that higher levels of profitability (in either the current or previous period) motivate growth in the British life insurance industry. Fok et al. (1997) find a significantly positive impact in the U.S. property-casualty insurance sector. Consequently, our second hypothesis is:

H1b: The impact of firm profitability on growth is non-linear (U-shape).

Arguments for a positive impact of risk on profitability can be found across several disciplines. In finance, the Capital Asset Pricing Model (CAPM) assumes a linear positive relationship between risk and return (Sharpe, 1964). Riskier investments should be compensated with higher returns. Fairley (1979) illustrates that profit margins in property-liability insurance equal returns estimated from the CAPM. Hill (1979) argues that a fair profit rate in insurance prices can be estimated by the CAPM. Insurers having riskier assets and insurance portfolios should exhibit higher profit margins. These arguments imply a positive impact of risk on profitability.

However, if the risk exceeds a certain threshold, particularly when risk endangers the investment grade rating, or even the solvency of a firm, the classical CAPM prediction may not hold anymore. Wakker, Thaler, and Tversky (1997) illustrate that an increase in the insolvency risk drastically reduces the willingness to pay for insurance. Sommer (1996) finds that the insolvency risk negatively affects prices in property-liability insurance. Also, Phillips, Cummins, and Allen (1998) show that insurance prices in multiple line insurance are negatively affected by the insolvency risk, where the effect is stronger for long-tail business. Baranoff and Sager (2007) observe reduced demand for life insurance products, as measured by the number of policies written, when ratings decline. Eling and Schmit (2012) state that a detoriation of an insurer's financial condition should reduce new and renewal business. Thus, falling output prices, and all other things (e.g., input prices) being unchanged, leads to a decrease in profitability (Lawrence, Diewert, & Fox, 2006). Therefore, at very high levels endangering the solvency, the impact of risk on the return may be negative. Hence, firms cannot unlimitedly and linearly increase returns by increasing risk. Rather, there is a critical

[8] Here, we assume that earnings are retained and reinvested in sales-growth activities.

point up to which the relationship is positive and beyond which it is reversed. Thus, our third hypothesis is:

H2a: The impact of firm risk on profitability is non-linear (inverted U-shape).

Prospect theory predicts that managers of relatively unprofitable firms seek higher risks by implementing corrective processes to improve profitability (Jegers, 1991). The lower the actual return is, the more managers are willing to take risks and are considered to be risk-seeking. In this situation, the impact of profitability on risk is negative (Bowman, 1982). On the flip side, when the actual return of a firm is relatively high, the management tends to be risk-averse. Risk-averse management will only undertake risky decisions if they are rewarded with appropriate returns, as is also suggested by the CAPM (Nickel & Rodriguez, 2002). In this sense, the impact of profitability on risk is positive (Fiegenbaum, 1990).

The predictions of prospect theory imply that the actual profitability of a firm influences the risk-taking decisions of that firm. Thus, the impact of firm profitability on risk exhibits a U-shape (see Appendix B for an illustration of the prospect theory vs. CAPM). Chang and Thomas (1989) confirm the U-shaped impact of risk on profitability for U.S. manufacturing firms. Fiegenbaum and Thomas (1988) illustrate that this relationship holds within and across industries, as well as over time. To the best of our knowledge, the implications of prospect theory have not been empirically tested at the organizational level in the financial services sector. Hence, we define our fourth hypothesis as:

H2b: The impact of firm profitability on risk is non-linear (U-shape).

As discussed above, growth to a larger scale of operation makes risk pooling more effective (Cummins & Rubio-Misas, 2006). In this way, the law of large numbers and the potential risk diversification effect are considered, which stabilize the underwriting results and reduce the firm risk. Furthermore, an increasing firm size may consequently increase safety, as larger insurers tend to have lower failure rates (Cheng & Weiss, 2012). Positive and reasonable growth indicates a healthy and active operation and reflects the attractiveness of the firm to its clients and investors; such firms are more likely to stay financially stable (Zhang & Nielson, 2015).

However, rapid premium growth in insurance, for example, driven by an aggressive sales and underwriting strategy, is generally regarded as a cause of increased risk (Kim et al., 1995; Fok et al., 1997; Rauch & Wende, 2015). Barth and Eckles (2009) emphasize that insurers using inadequate pricing as a growth strategy may face solvency issues, when claims are due and reserves were not formed sufficiently high. Furthermore, rapid growth adds a high volume of new and potentially unfamiliar business to the insurance company bearing various risk sources (Barth & Eckles, 2009).

According to Zhang and Nielson's (2015) evidence, the impact of growth is two-fold: while a positive and reasonable growth rate shows that the insurer is in good shape, the authors warn that insurers which grow too quickly might experience trouble. Following this, we define our fifth hypothesis as:

H3a: The impact of firm growth on risk is non-linear (U-shape).

Higher risk-taking activities, for example, exploring new distribution channels, may surge sales. As the nature of financial services is assuming new risks, growth is only possible when risk taking is accepted. In turn, no risk taking means no business. Thus, it is intuitive that increasing risks leads to growth. However, when the risk is as high as endangering the solvency or investment grade rating of an insurer, the insurance demand may be adversely affected.

Eling and Schmit (2012) find negative premium changes after rating downgrades. Similarly, Epermanis and Harrington (2006) illustrate significant premium declines after financial strength downgrades, thus demonstrating the risk sensitivity of insurance demand. Baranoff and Sager (2007) also show that demand for life insurance declines after downgrading. Furthermore, Zanjani (2002) finds a significant positive relationship between the default risk and lapses in life insurance. Therefore, risk taking activities may boost growth, to a certain point, but when risk endangers the solvency, the demand and consequent firm growth are expected to decline. Thus, we define our last hypothesis:

H3b: The impact of firm risk on growth is non-linear (inverted U-shape).

3 Data, measures, and methodology

3.1 Data and measures

Our sample contains life and non-life insurer data from Best's Insurance Reports (2002–2013). Data was obtained for insurers domiciled in the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Spain, Switzerland, and the UK.[9] The 16 countries were selected because of good data availability. In addition, these countries are relatively homogenous, in terms of economic development and insurance market maturity, which leads to comparable challenges in managing growth, profitability, and safety.

We use accounting data[10] on a firm-year basis to measure growth, profitability, and safety. In line with the previous literature (Barth & Eckles, 2009; Ma & Ren, 2012; Cole et al., 2015), we measure growth for firm i in year t by the inflation-adjusted change in gross written premiums, as shown in Equation (1); in robustness tests, we also consider the inflation-adjusted changes in net written premiums and total assets as alternative growth measures.

$$Growth_{i,t} = \frac{Gross\ written\ premiums_{i,t}}{Gross\ written\ premiums_{i,t-1}} - 1\,. \tag{1}$$

Profitability is commonly measured with the return on equity (ROE) (Greene & Segal, 2004; Leverty & Grace, 2010), as shown in Equation (2). In robustness tests, we also consider the return on assets (ROA) as an alternative profitability measure. The ROA is less favorable than the ROE when analyzing life and non-life insurers in one sample, because the business model of life insurers is different from that of non-life insurers, resulting in much higher leverage ratios, and thus, significantly smaller ROA values (Eling & Jia, 2016). In Equation (2), we use profit (or loss) before taxes to account for country differences in tax rates. Equity includes both capital and surplus.

$$Profitability_{i,t} = \frac{Profit_{i,t}}{(Equity_{i,t} + Equity_{i,t-1})/2}\,. \tag{2}$$

Safety is captured by the level of firm risk. It is frequently assessed by the moving standard deviation of annual firm profitability in the empirical research (Cheng,

9 We exclude composite insurers, because they are mainly parental companies of life and non-life insurers whose information is already considered in the subsidiaries in our sample. In addition, we exclude insurers in run-off and in liquidation, as their business activities are not comparable with the strategies of the other insurance companies in our sample. Other European countries are not considered, because the database lacks enough years of observations for these countries.

10 Stock market data may be a complement to accounting data, but using stock data would drastically reduce the sample size. This is because, only a minority of the stock insurance companies are publicly traded and those few which are publicly traded often exhibit no liquid stocks. Therefore, accounting data is preferred over stock market data in this analysis.

Elyasiani, & Jia, 2011; Ho, Lai, & Lee, 2013).[11] In the core model, we consider a four-year period, as shown in Equation (3). In the robustness tests, we alternatively consider five- and six-year periods.

$$Risk_{i,t} = \sqrt{\frac{1}{(t-(t-3))} \sum_{x=t-3}^{t} (Profitability_{ix} - \emptyset Profitability_i)^2}, \tag{3}$$

where x denotes an index and $\emptyset Profitability$ denotes the mean firm profitability from $t - 3$ to t.

In later regression analyses, we control for firm characteristics and market conditions that influence firm growth, profitability, and risk. We account for the organizational form with a binary variable, where 1 indicates that the insurer is a mutual firm and 0 indicates that it is a stock. We also control for the line of business with a binary variable, where 1 indicates a life insurer and 0 indicates a non-life insurer. In addition, we account for the firm size by the natural logarithm of total assets.

We capture the market effects by industry growth, industry profitability, and industry risk, represented by the country-year averages of the firm growth, profitability, and risk measures, respectively. Furthermore, to proxy the overall economic well-being, we control for the annual real GDP growth, the long-term interest rate (government bonds maturing in ten years), and the inflation rate. We measure market competition by the concentration ratio calculated as the sum of the market share percentage held by the four largest insurers in each country (Cummins & Weiss, 2004; Fenn et al., 2008; Huang & Eling, 2013). The higher the concentration ratio is, the less competitive the market is. As stated previously, insurers adapt their strategic goals to the state of the market. Thus, we control for the maturity of the insurance market with the penetration ratio. Except for inflation, the market condition measures are given for non-life and life insurers separately. All absolute values are deflated to 2002 using the consumer price index. The macroeconomic factors are obtained from the AXCO Insurance Information Services and/or the Organisation for Economic Co-operation and Development.

The sample is truncated at the 1st and 99th percentiles of the growth, profitability, and safety measures to reduce the impact of outliers (Kanagaretnam, Lim, & Lobo, 2011; Fields et al., 2012; in later robustness tests, the threshold values for trimming will be varied). The final sample consists of 1,988 insurance companies (9,298 firm-year observations). Among these companies, 34% operate in the life insurance industry and

[11] Alternatively, risk (safety) could be measured in accordance with regulation practices (e.g., the Insurance Regulatory Information System (IRIS) and the Financial Analysis and Surveillance Tracking (FAST) system in the U.S.) (Chen & Wong, 2004) or the solvency ratios, according to Solvency II in the EU or the RBC standards in the U.S. (Liu et al., 2017). Moreover, business risk could be proxy by asset and product risk measures (Baranoff, Papadopoulos, & Sager, 2007; Eling & Marek, 2014). However, due to data limitations, we cannot apply these approaches.

66% in the non-life insurance industry; 23% are mutual companies and 77% are stock companies. Table 2 summarizes our sample by country and line of business.

Table 2 Sample by country and by line of business

Country	Life	Non-life	Total	Firm-year observations
Austria	3	11	14	75
Belgium	10	41	51	257
Denmark	41	89	130	551
Finland	25	21	46	252
France	45	100	145	673
Germany	233	228	461	2,609
Ireland	38	94	132	525
Italy	40	59	99	416
Luxembourg	9	13	22	71
Netherlands	36	130	166	735
Norway	13	38	51	185
Portugal	11	14	25	103
Spain	56	129	185	953
Sweden	28	92	120	373
Switzerland	21	83	104	408
United Kingdom	62	175	237	1,112
Total	671	1,317	1,988	9,298

Table 3 presents the summary statistics for the three strategic goals, firm characteristics, and market conditions used in later regression analyses.

Table 3 Summary statistics (N= 9,298)

Variable/statistic	Mean	Std. Dev.	Min.	25th	Median	75th	Max.
Strategic goals							
Growth	0.049	0.251	-0.686	-0.057	0.027	0.117	3.311
Profitability	0.123	0.173	-0.723	0.034	0.111	0.208	0.806
Risk (safety)	0.107	0.103	0.005	0.041	0.076	0.137	0.876
Firm characteristics							
Organizational form (mutual=1, stock=0)	0.225	0.418	0	0	0	0	1
Line of business (life=1, non-life=0)	0.337	0.473	0	0	0	1	1
Firm size (millions USD)	4,905	16,844	0,000	0,091	0,504	2,877	537,494
Market conditions							
Industry growth	0.049	0.099	-0.298	-0.015	0.038	0.104	1.634
Industry profitability	0.123	0.063	-0.307	0.090	0.126	0.160	0.467
Industry risk	0.107	0.041	0.029	0.083	0.094	0.123	0.416
GDP growth	0.010	0.025	-0.085	0.002	0.011	0.031	0.066
Long-term interest rate	0.035	0.014	0.006	0.026	0.037	0.042	0.106
Inflation	0.020	0.012	-0.045	0.014	0.022	0.026	0.049
Concentration ratio	0.505	0.143	0.340	0.380	0.440	0.600	0.920
Penetration ratio	0.039	0.021	0.015	0.029	0.032	0.038	0.148

3.2 Methodology

To test our hypotheses, we specify a SEM as follows:[12]

$$Growth_{i,t} = \gamma_{1,1}Profitability_{i,t} + \gamma_{1,2}Profitability_{i,t}^2 + \gamma_{1,3}Risk_{i,t} + \gamma_{1,4}Risk_{i,t}^2 + \gamma_{1,5}CV_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$Profitability_{i,t} = \gamma_{2,1}Growth_{i,t} + \gamma_{2,2}Growth_{i,t}^2 + \gamma_{2,3}Risk + \gamma_{2,4}Risk_{i,t}^2 + \gamma_{2,5}CV_{i,t} + \omega_{i,t} \quad (5)$$

$$Risk_{i,t} = \gamma_{3,1}Profitability_{i,t} + \gamma_{3,2}Profitability_{i,t}^2 + \gamma_{3,3}Growth_{i,t} + \gamma_{3,4}Growth_{i,t}^2 + \gamma_{3,5}CV_{i,t} + \vartheta_{i,t}, \quad (6)$$

where γ_{gj} is the coefficient for variable j in equation g, CV represents a matrix of all other exogenous control variables (Table 3), and $\varepsilon_{i,t}$, $\omega_{i,t}$, and $\vartheta_{i,t}$ are the error terms.[13]

To test for the impact of the non-linear terms, we apply a hierarchical regression analysis (Lechner, Frankenberger, & Floyd, 2010). We first estimate Equations (4) to (6) without the quadratic terms of the primary explanatory variables (i.e., the right-hand side endogenous variables) and denote this as Model (1). We then include the quadratic terms, as presented in Equations (4) to (6), and call this Model (2). Conclusions about the non-linear (U-shape or inverted U-shape) relationships, if any, are drawn as follows. We plot the bivariate relationship if the SEM results suggest a U-shape or inverted U-Shape (Haans, Piters, & He, 2015). Next, we follow the three steps proposed by Lind and Mehlum (2010): first, we examine the sign and significance of the coefficients of the linear and quadratic terms. Second, we perform slope tests at the lower and upper data range. Third, we analyze whether the turning point is located within the data range.

We use both two-stage least squares (2SLS) and ordinary least squares (OLS) to estimate the non-recursive SEM, subject to the following steps. First, we test whether growth, profitability, and risk are indeed endogenous. The Hausman specification test rejects the null hypotheses of no endogeneity (McShane, Cox, & Butler, 2010).[14]

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[12] An alternative approach is to take safety as a limited decision-making variable, assuming insurers mainly focus not to undercut regulatory solvency requirements (or a target rating) and only analyze the links between growth and profitability. Appendix F illustrates this case. The results in Appendix F are consistent with our main results. In the main body of the paper, we use the SEM with three dimensions because, in reality, insurers actively manage their safety levels in addition to the fulfillment of regulatory requirements, for example, to achieve certain financial strength ratings. Empirically, many insurers also keep their solvency ratios way above the trigger of regulatory interventions.

[13] The Hausman specification test provides evidence of endogeneity of the SIZE control variable at the 1% significance level. To address tis concern, we lag this variable by one period in all regression equations, so that feedback between SIZE and the dependent variables can be precluded. This approximation does not change the relative size positions for most insurers and thus still successfully controls for the scale of firms.

[14] We regress growth, profitability, and risk one by one on all independent and instrumental variables to obtain three vectors of residuals; the residuals are then added to Equations (4) to (6). In the growth equation, the residuals from the profitability regression are significant at the 1% level (standard error (SE): 0.031; p-value: 0.000) and the residuals from the risk regression are significant at the 10% level (SE: 0.054; p-value: 0.093). In the profitability equation, the residuals from the growth regression are significant at the 1% level (SE: 0.019; p-value: 0.000) and the residuals from the risk regression are significant at the 1% level (SE: 0.036; p-value: 0.000). In the risk equation, the residuals from the growth regression are significant at the 1% level (SE: 0.012;

Therefore, simultaneous equation techniques (e.g., 2SLS) with instrument variables should be used. The industry indicators (Shiu, 2013) and lagged values of growth, profitability, and risk (Goddard, Molyneux, & Wilson, 2011) are candidates of instruments for the corresponding firm measures.[15] If all six instruments are used, the three equations of Model (1) are over-identified according to the order condition. Because the Hausman test for over-identifying restrictions (Wooldridge, 2010) is significant at the 1% level in this case, the choice of instruments must be reconsidered. Generally, any subset of the instruments that just identifies the SEM can be used (Wooldridge, 2010). We choose industry growth, lagged profitability, and lagged risk as instruments because this choice produces the highest test statistics in the F-tests for weak instruments.

All control variables are identical in all equations of the SEM, except for industry growth and the one-period lagged profitability and risk, which are only included in the growth, profitability, and risk equations, respectively. Consequently, all three equations of Model (1) are just identified as suggested by the order condition. In addition, the equations of Model (1) can be identified according to the rank condition. We follow Wooldridge (2010) and use the square of the fitted values from the first-stage as the instruments for the quadratic terms of growth, profitability, and risk in Model (2); we relabel the quadratic terms in Model (2) to be new endogenous variables to confirm the rank condition (Wooldridge, 2010). This indicates that 2SLS, a limited information (single-equation) approach, can be used (Greene, 2009).

To confirm the choice of instruments, we test for problems with weak instruments. The F-tests reject the null hypothesis of the existence of weak instruments (Appendix D). In addition, we apply IPS tests (Im, Pesaran, & Shin, 2003), which reject the null hypothesis that all our panels contain a unit root.[16]

p-value: 0.000) and the residuals from the profitability regression are significant at the 1% level (SE: 0.014; p-value: 0.000).

15 Instruments have to fulfill two conditions (Wooldridge, 2010). First, they must be uncorrelated with the error terms. Second, they must be partially correlated with the endogenous variable for which the instrument serves. The industry levels are good instruments, because they only influence the respective growth, profitability, and risk of the individual firms. In our sample, no firm has enough substantial market power to fundamentally change the industry results. The lagged values are also good instruments, because growth, profitability, and risk should be persistent over time (Goddard, Molyneux, & Wilson, 2011, review profit persistence in banking). Thus, the instruments are expected to be positively correlated with the endogenous variables (Appendix F), but unrelated to the error terms in the current period.

16 We balance our sample to conduct the IPS test. In a first step, we consider no mean, no trend, and up to three lags in the data generating process. In a second step, we consider also a mean and a trend. All 18 test statistics are significant and thus rejecting the null hypothesis that all panels contain unit roots. Available tests for unbalanced panels have the disadvantage that they usually require a longer period than we have available (e.g., the test of Levin, Lin, & Chu, 2002). Nevertheless, if the IPS test rejects the null hypothesis that all panels contain a unit root, this result could be accepted for the full sample. Our result is line with Harrington and Yu (2003), who reject a unit root for underwriting profitability ratios (i.e., loss ratios, expense ratios, combined ratios, and economic loss ratio)

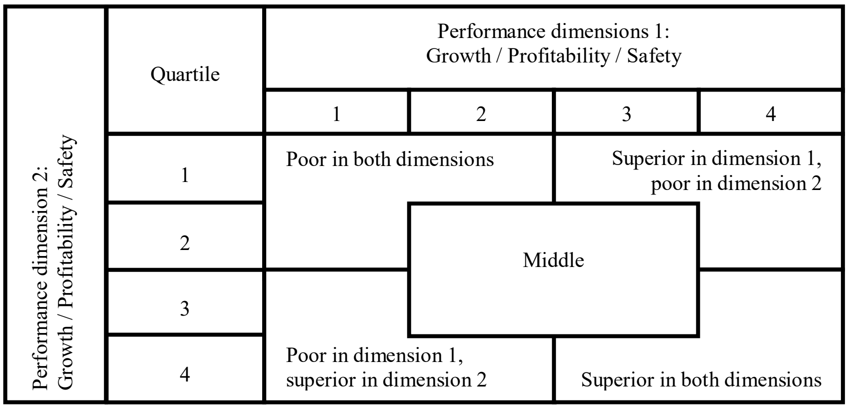
The 2SLS proceeds as follows. In the first-stage, the observed values of growth, profitability, and risk are separately regressed against all exogenous variables appearing in the SEM by OLS (Wooldridge, 2010). The first-stage regression results are shown in Appendix D. In the second-stage, Equations (4) to (6) are estimated; the fitted values from the first-stage replace the observed values of growth, profitability, and risk, appearing anywhere on the right-hand side of the equations. We use the square of the fitted values from the first-stage as the instruments for the quadratic terms of growth, profitability, and risk (Wooldridge, 2010). In Appendix C, we show the full 2SLS estimation procedure. Because all equations of an SEM are just identified, 2SLS should produce consistent results with indirect least squares and three-stage least squares.

Notwithstanding the quality of the instruments, 2SLS generally tends to be less efficient than OLS. Furthermore, multicollinearity is likely to become a concern in 2SLS estimations. Rhoads (1991) discusses that multicollinearity is a common and inevitable problem in 2SLS. Introducing country and year dummies would further intensify the multicollinearity problem, leading to reduced significance of many coefficients and uninterpretable results as shown in the Appendices G and H.[17] Due to the tradeoff between 2SLS and OLS, we present results for both estimations; we estimate 2SLS without fixed effects, and OLS with the country and year fixed effects as our core model. The 2SLS and OLS results are in general consistent with respect to our hypotheses. For the magnitudes of coefficients that are used to derive the turning point, we rely on the OLS results because they are more efficient.

We also conduct a non-parametric analysis following Davidsson et al. (2009). This approach takes advantage of the long sample period and demonstrates how firms move in two-dimensional performance spaces (i.e., growth-profitability, safety-profitability, growth-safety spaces) over various time windows. In each space, firms are classified into five groups, based on their relative performance in each time period, as illustrated in Figure 1. We are especially interested in how firms transit into the “superior in both dimensions” and “poor in both dimensions” groups during the chosen time periods. We test the significance of our results using standard z-tests (Davidsson et al., 2009). Alternatively, we analyze Granger causality among growth, profitability, and safety (Granger, 1969). The results suggest that feedback relationships exist (i.e., causal relationships in both directions) among the three dimensions and are consistent with our hypothesis development and the empirical analyses (See Appendix I).

[17] Introducing country and year dummies in the 2SLS estimation increases the average VIF in all equations significantly. In Model (2), the average VIF are significantly higher than in the OLS estimation considering country and year dummies. Furthermore, while the VIF for the growth terms do not increase significantly in the OLS estimations with and without the country and year dummies, the VIF for the linear (quadratic) growth terms increase by approximately 84% (33%) and 72% (31%) in Equations (5) and (6), respectively, of the 2SLS estimation considering country and year dummies. This occurs because the predicted values of the endogenous variables, used in the second-stage regressions, are basically linear combinations of all exogenous variables (Rhoads, 1991).

Figure 1 Sample classification by performance groups



4 Results

4.1 Simultaneous equation model (SEM)

Tables 4 and 5 present the 2SLS and OLS regression results, respectively. Model (1) only considers the linear terms of the strategic goal measures. In Model (2), we also include the quadratic terms. In Table 6, we follow Cummins and Xie (2013) and Biener, Eling, and Wirfs (2016) to analyze average profitability, growth, and risk by deciles.

Table 4 2SLS regression results

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.217^{***} (0.019)	-0.036^{***} (0.007)		0.252^{***} (0.020)	-0.051^{***} (0.009)
$Growth^2$					-0.060^{***} (0.016)	0.023^{**} (0.011)
Profitability	0.024 (0.036)		-0.045^{***} (0.009)	-0.005 (0.066)		-0.163^{***} (0.018)
$Profitability^2$				0.072 (0.161)		0.327^{***} (0.046)
Risk	-0.010 (0.034)	0.184^{***} (0.024)		0.087 (0.088)	0.285^{***} (0.054)	
$Risk^2$				-0.212 (0.165)	-0.210^{**} (0.106)	
$Profitability_{t-1}$		0.470^{***} (0.019)			0.468^{***} (0.019)	
$Risk_{t-1}$			0.756^{***} (0.010)			0.733^{***} (0.010)
Organizational form (mutual=1, stock=0)	-0.029^{***} (0.006)	-0.023^{***} (0.003)	-0.004^{**} (0.002)	-0.029^{***} (0.006)	-0.022^{***} (0.003)	-0.004^{***} (0.002)
Line of business (life=1, non-life=0)	0.015^{**} (0.007)	-0.012^{***} (0.004)	-0.002 (0.001)	0.016^{**} (0.007)	-0.011^{***} (0.004)	-0.002^{*} (0.001)
Ln(Firm size)$_{t-1}$	-0.007^{***} (0.001)	0.004^{***} (0.001)	0.001^{**} (0.0003)	-0.007^{***} (0.001)	0.004^{***} (0.001)	0.001^{**} (0.0003)
Industry growth	0.989^{***} (0.066)			0.989^{***} (0.066)		
GDP growth	-0.009 (0.129)	-0.121 (0.075)	-0.228^{***} (0.028)	0.003 (0.129)	-0.137^{*} (0.075)	-0.205^{***} (0.028)
Long-term interest rate	-0.211 (0.189)	-0.257^{**} (0.118)	0.195^{***} (0.047)	-0.240 (0.190)	-0.234^{*} (0.120)	0.149^{***} (0.046)
Inflation	-0.020 (0.294)	-0.832^{***} (0.166)	0.253^{***} (0.057)	-0.038 (0.294)	-0.790^{***} (0.167)	0.220^{***} (0.057)
Concentration ratio	0.009 (0.018)	-0.016 (0.012)	0.007^{*} (0.004)	0.006 (0.018)	-0.017 (0.012)	0.007^{*} (0.004)
Penetration ratio	-0.0002 (0.149)	-0.211^{**} (0.084)	0.116^{***} (0.030)	-0.007 (0.149)	-0.216^{**} (0.084)	0.111^{***} (0.029)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.159	0.262	0.671	0.159	0.263	0.675
F Statistic	50^{***}	130^{***}	645^{***}	44^{***}	115^{***}	618^{***}
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No
Main conclusions				No evidence for H1b (P→G: no U, insignificant)	Evidence for H1a (G→P: inverted U)	Evidence for H2b (P→R: U)
				No evidence for H3b (R→G: insignificant)	Multicollinearity concerns for H2a (R→P; no inverted U; refer to OLS)	Evidence for H3a (G→R: U)

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported. Growth=G, Profitability=P, Risk=R, U shape=U, inverted U shape=inverted U.

Table 5 OLS regression results

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.025*** (0.006)	0.0002 (0.002)		0.051*** (0.009)	-0.004 (0.003)
$Growth^2$					-0.025*** (0.006)	0.003 (0.002)
Profitability	0.049*** (0.014)		-0.069*** (0.004)	0.030* (0.017)		-0.142*** (0.004)
$Profitability^2$				0.084** (0.039)		0.352*** (0.008)
Risk	-0.013 (0.024)	-0.046*** (0.015)		0.016 (0.058)	0.062* (0.036)	
$Risk^2$				-0.109 (0.106)	-0.222*** (0.067)	
$Profitability_{t-1}$		0.476*** (0.009)			0.473*** (0.009)	
$Risk_{t-1}$			0.755*** (0.006)			0.708*** (0.005)
Organizational form (mutual=1, stock=0)	-0.030*** (0.006)	-0.026*** (0.004)	-0.005*** (0.002)	-0.029*** (0.006)	-0.025*** (0.004)	-0.0004 (0.001)
Line of business (life=1, non-life=0)	0.017** (0.007)	-0.014*** (0.004)	0.001 (0.002)	0.017*** (0.007)	-0.012*** (0.004)	-0.0001 (0.001)
$Ln(Firm\ size)_{t-1}$	-0.007*** (0.001)	0.005*** (0.001)	0.001** (0.0003)	-0.007*** (0.001)	0.005*** (0.001)	0.001*** (0.0003)
Industry growth	0.997*** (0.035)			0.998*** (0.035)		
GDP growth	-0.021 (0.258)	0.119 (0.163)	0.008 (0.064)	-0.019 (0.258)	0.101 (0.163)	0.040 (0.058)
Long-term interest rate	-0.024 (0.315)	0.140 (0.198)	0.210*** (0.077)	-0.048 (0.315)	0.135 (0.198)	0.111 (0.071)
Inflation	-0.060 (0.343)	0.615*** (0.217)	0.256*** (0.084)	-0.072 (0.343)	0.630*** (0.216)	0.150* (0.077)
Concentration ratio	-0.015 (0.041)	0.124*** (0.026)	-0.045*** (0.010)	-0.014 (0.041)	0.121*** (0.026)	-0.028*** (0.009)
Penetration ratio	0.018 (0.161)	-0.185* (0.102)	0.030 (0.040)	0.024 (0.161)	-0.168* (0.102)	0.038 (0.036)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.189	0.529	0.854	0.190	0.530	0.878
F Statistic	65***	308***	1,595***	61***	293***	1,856***
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Main conclusions				No evidence for H1b (P→G: no U, but positive) No evidence for H3b (R→G: insignificant)	Evidence for H1a (G→P: inverted U) Evidence for H2a (R→P; inverted U)	Evidence for H2b (P→R: U) No evidence for H3a (G→R: No U, insignificant)

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. A constant term, country and year dummies are included to account for country and year fixed effects, but not reported. Growth=G, Profitability=P, Risk=R, U shape=U, inverted U shape=inverted U.

Table 6 Deciles of growth, profitability, and risk

		Growth range		Average		Profitability range		Average		Risk range		Average	
	N	Min	Max	Profita.	Risk	Min	Max	Growth	Risk	Min	Max	Growth	Profita.
Q1	583	-0.68	-0.15	0.07	0.13	-0.72	-0.04	0.01	0.19	0.00	0.02	0.04	0.09
Q2	583	-0.15	-0.08	0.09	0.12**	-0.04	0.02	0.02	0.09***	0.02	0.04	0.05	0.11***
Q3	583	-0.08	-0.04	0.10**	0.11	0.02	0.05	0.03	0.08***	0.04	0.05	0.05	0.14***
Q4	583	-0.04	-0.01	0.11	0.12***	0.05	0.08	0.04	0.08	0.05	0.06	0.06	0.14
Q5	583	-0.01	0.03	0.12	0.10	0.08	0.11	0.03	0.08	0.06	0.08	0.06	0.14
Q6	583	0.03	0.06	0.13**	0.10	0.11	0.14	0.07***	0.09***	0.08	0.09	0.04	0.14
Q7	583	0.06	0.09	0.14	0.10	0.14	0.18	0.05	0.09	0.09	0.12	0.06	0.14
Q8	583	0.09	0.14	0.16***	0.10	0.18	0.24	0.07**	0.10	0.12	0.16	0.05	0.15**
Q9	583	0.14	0.23	0.18**	0.11*	0.24	0.33	0.07	0.11***	0.16	0.23	0.04	0.11***
Q10	583	0.23	3.31	0.14***	0.11	0.33	0.81	0.09**	0.16***	0.23	0.88	0.03	0.08***

Notes: Tests of significance is based on a two-sample t-test (two-tailed). ***, **, and * represent significant differences of the quantile mean from the preceding quantile mean at the 1%, 5%, and 10% levels, respectively. The significance level for the first decile is not applicable.

H1a: The impact of firm growth on profitability is non-linear (inverted U-shape).

Table 4 illustrates a positive and significant coefficient for the linear growth term in the profitability equation in both Models (1) and (2). The coefficient of the quadratic growth term is negative and significant in Model (2). The results indicate a non-linear (inverted U-shape) impact of firm growth on profitability. This evidence is reinforced by the OLS results in Table 5. The slopes at both ends of the data range are sufficiently steep and the turning point (102%=[-0.051/(2*-0.025)]), after which the positive impact of growth becomes negative, is located within the data range, supporting the inverted U-shape (Haans et al., 2015).[18] Figure 2 plots growth against profitability and illustrates a quadratic fit, also supporting the inverted U-shape.

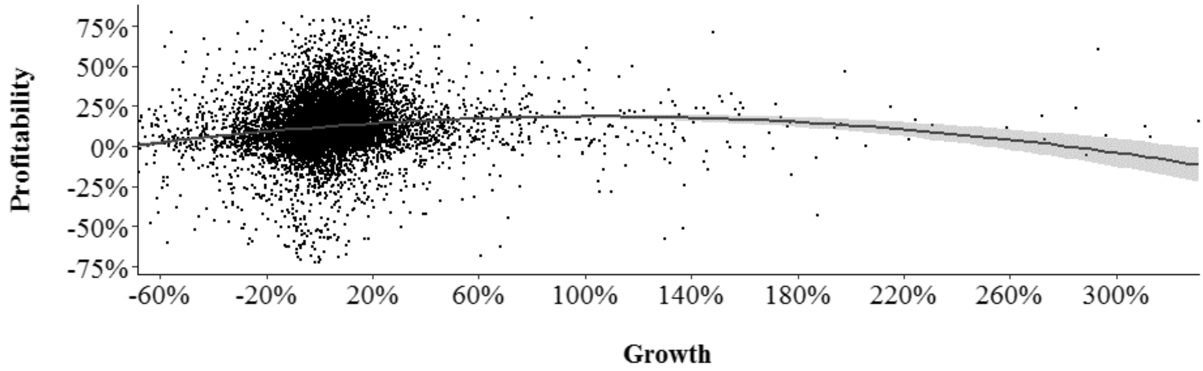
According to the estimated turning point and Figure 2, insurers operate in the situation of profitable growth up to considerably high growth rates. Only for extremely high growth rates, does the positive impact of growth not hold anymore. Table 6 shows that firms' average profitability increases up to the ninth growth decile in our sample. Only in the tenth decile is the average profitability significantly lower than that in the preceding decile.

The drawbacks of an extremely high firm growth may explain its negative impact on profitability. For example, high growth may result from M&A activities (i.e., inorganic growth). Obstacles (e.g., increased complexity) that come with high growth and lead to perceptible rising costs are especially concise here. Cummins and Weiss (2004) document average negative abnormal returns for the acquirer in a European insurer sample. Rapidly growing firms may also encounter profitability difficulties, due to the aging phenomenon (D'Arcy & Gorvett, 2004). Furthermore, high growth may result from underpricing, which comes at the expense of profitability if the claim requirement remains unchanged.[19] Overall, the results support H1a and underline the empirical findings of Ramezani et al. (2002). However, the negative impact of additional firm growth on profitability only results from 10% of the insurers in our sample with extremely high growth rates (Table 6).

[18] As discussed, we present the turning point of the more efficient OLS estimation if both the 2SLS and OLS estimation show consistent results. The turning point should not be interpreted as the optimal growth rate. Testing for non-linearity in the SEM only allows inferences about the existence of goal conflicts. The location of the turning point is heavily influenced by the distribution of the observations and depends on the efficiency of the estimation. Multiple robustness tests (e.g., alternative trimming) validate the inverted U-shape, but the range of the turning points is relatively wide. In Table 6, we follow Cummins and Xie (2013) and Biener, Eling, and Wirfs (2016) to analyze average profitability by growth deciles.

[19] German motor insurance can be used as an example for the economic damage due to underpricing in the competition for customers (Eling & Luhnen, 2008). In German motor insurance, premiums generally do not reflect the actual loss requirements; hence, the pricing is not necessarily based on actuarial aspects. Instead, the pricing is rather oriented to strategic aspects (e.g., distribution and marketing considerations). As a consequence, the underwriting results have deteriorated over time.

Figure 2 Relationship between growth and profitability



Notes: The chart plots firm growth against profitability in the bivariate space. The curve represents the quadratic fit; the grey shaded area illustrates the 95% confidence interval.

H1b: The impact of firm profitability on growth is non-linear (U-shape).

In Model (1) of the 2SLS estimation (Table 4), the coefficient of the linear profitability term in the growth equation is positive but insignificant. In Model (2), the coefficients of both the linear and quadratic profitability terms are insignificant. In Models (1) and (2) of the OLS estimation (Table 5), the coefficients of the linear term are positive and significant. In addition, the coefficient of the quadratic profitability term is significantly positive. This finding suggests an upward impact of profitability on growth (i.e., the impact is positive and greater than a linear increase). Thus, the OLS results indicate that profitable firms have more resources to invest in growth. The increase may be more than proportional, because a firm has higher incremental internal resources if dividend payments do not increase proportionally with the level of profitability. The positive impact is also revealed in the 2SLS estimation considering changes in assets as growth measure (Appendix N).[20] Overall, we find no evidence for the expected U-shape but evidence for a positive impact of firm profitability on growth. This result concurs with that of Fok et al. (1997).

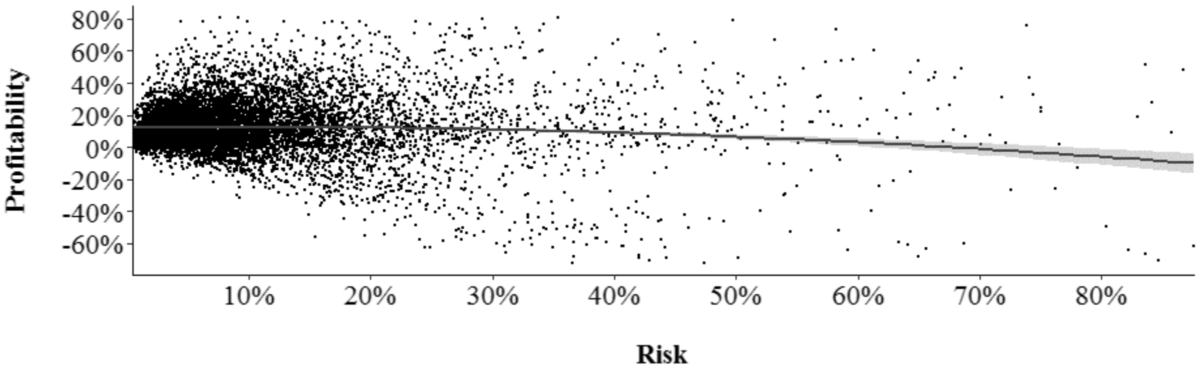
H2a: The impact of firm risk on profitability is non-linear (inverted U-shape).

The coefficient of the linear risk term is positive and significant in the profitability equation of both Models (1) and (2), as shown in Table 4. In Model (2), the quadratic risk term is negative and significant. Also, in the OLS estimation (Table 5), the linear and quadratic risk terms show the expected signs and are significant providing evidence for the expected inverted U-shape. Although Figure 3 reveals that the curve may exhibit a "sideways j", rather than an inverted U-shape, the analyses of the slopes and the turning point (14%=[-0.062/(2*-0.222)]) based on the OLS results support the existence

[20] To save space, we do not present the bivariate relationship in a figure if the SEM results do not provide support for a U-shape or inverted U-shape. However, the figures are available upon request.

of the inverted U-shape.21 Thus, we find evidence in favor of H2a, with regard to the fact that insurers cannot unlimitedly and linearly increase returns by increasing risk. Although insurers underwriting riskier business and/or investing in riskier assets are rewarded with higher returns, profitability tends to decline at high levels of firm risk, probably due to the reduced willingness of the policyholders to pay for insurance from high-risk insurers (Sommer, 1996; Wakker, Thaler, & Tversky, 1997; Phillips, Cummins, & Allen, 1998). According to Table 6, the average profitability decreases significantly in the ninth and tenth risk deciles, showing that the negative impact only concerns the most risky insurers (less than 20% of all insurers in the sample).

Figure 3 Relationship between risk and profitability



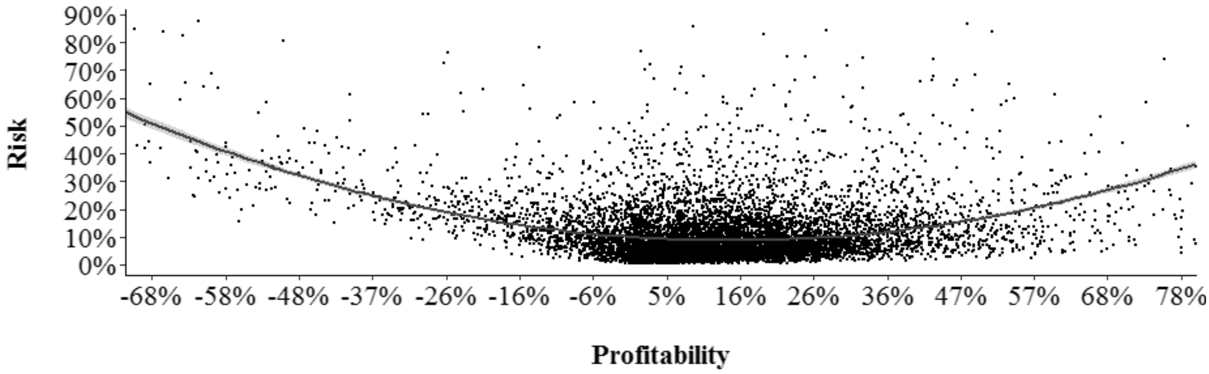
Notes: The chart plots firm risk against profitability in the bivariate space. The curve represents the quadratic fit, and the grey shaded area illustrates the 95% confidence interval.

H2b: The impact of firm profitability on risk is non-linear (U-shape).

In Table 4, the coefficient of the linear profitability term is negative and significant in the risk equation of Model (1). The coefficient of the quadratic profitability term in Model (2) illustrates a significantly positive sign, while the coefficient of the linear term is still significantly negative. This is evidence of a U-shaped impact of profitability (Figure 4 for an illustration), which is further supported by the OLS results (Table 5) and the slope- and turning point-tests (21%=[0.142/(2*0.352)]). Thus, our results suggest that insurers' management tends to take relatively high risks if the profitability is relatively low, which reveals a negative return-risk relationship and supports prospect theory. By contrast, firms that are located on the upward-sloping part of the curve tend to have risk-averse management (i.e., risks are rewarded with appropriate returns, as also predicted by the CAPM). Our findings, for the European insurance sector, are in line with the theoretical suggestions of prospect theory and the empirical evidence for the U-shaped impact of risk on profitability documented for various industries by Chang and Thomas (1989), as well as Fiegenbaum and Thomas (1988). Overall, we find support for H2b.

[21] The turning point may deviate from the turning point in the figure, because the figure only illustrates the bivariate relationship. The estimated turning point is a result of the OLS regression, including the control variables.

Figure 4 Relationship between profitability and risk



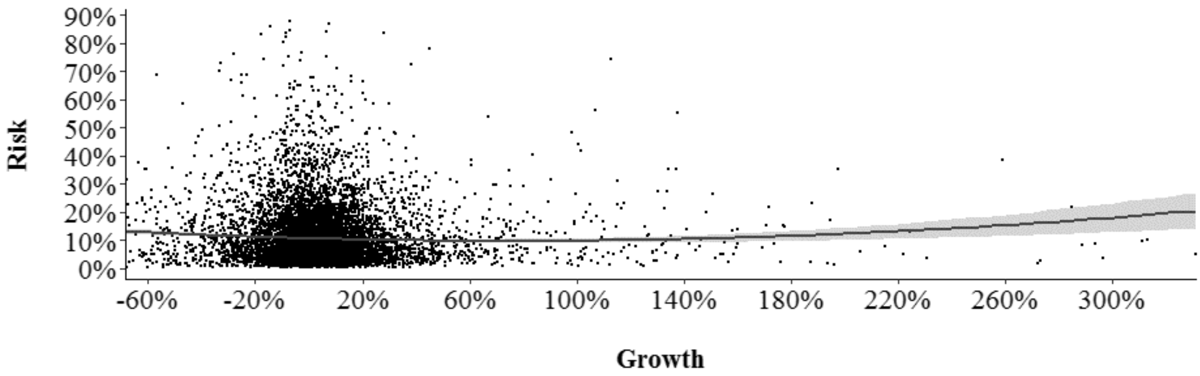
Notes: The chart plots firm profitability against risk in the bivariate space. The curve represents the quadratic fit. The grey shaded area illustrates the 95% confidence interval.

H3a: The impact of firm growth on risk is non-linear (U-shape).

Table 4 shows a negative and significant coefficient of the linear growth term in the risk equation of both Models (1) and (2). In addition, the quadratic growth term is positive and significant in Model (2). This combination of coefficients indicates the expected U-shaped impact (H3a). The slope- and turning point-tests (109%=[0.051/(2*0.023)]) and Figure 5 support this inference.[22] In Appendix S, which presents OLS results with year dummies per country, the U-shaped impact of growth on risk is confirmed. Thus, while moderate firm growth decreases risk due to, for example, improved diversification, extremely high growth increases firm risk. This result is in line with the claim that high growth is generally driven by aggressive sales and underwriting strategies that increase risks (Kim et al., 1995; Fok et al., 1997; Rauch & Wende, 2015). It also reflects that adding high volume of new and potentially unfamiliar business to the insurance company bears various risk sources (Barth & Eckles, 2009). Table 6 demonstrates that average risk increases significantly in the ninth growth decile, thus underlining that the positive impact on risk only concerns less than 20% of the insurers with extremely high growth rates. Overall, we find support for H3a.

[22] Since the results in Table 5 are insignificant, we refer to the turning point derived from the 2SLS estimation.

Figure 5 Relationship between growth and risk



Notes: The chart plots firm growth against risk in the bivariate space. The curve represents the quadratic fit; the grey shaded area illustrates the 95% confidence interval.

H3b: The impact of firm risk on growth is non-linear (inverted U-shape)

In both Tables (4) and (5), the risk coefficients in the growth equations are insignificant. Thus, we cannot confirm the expected non-linear (inverted U-shape) impact of firm risk on growth (H3b). Because the SEM reveals neither a linear (Model 1), nor a non-linear (Model 2), impact of risk, we further examine whether extremely low and high risk impact growth. Appendix J illustrates the tail dependence between the inverse firm risk measure and growth (Patton, 2012) for different quantiles. It illustrates that the tail dependence for lower quantiles is slightly higher than that for higher quantiles; for example, the tail dependence for the 10th (20th) percentile is approximately 0.15 (0.24), whereas the tail dependence for the 90th (80th) is only approximately 0.07 (0.17). Thus, the tail dependence analysis concludes that growth is especially sensitive to high risk. This concurs with the results in the literature (Zanjani, 2002; Epermanis & Harrington, 2006; Baranoff & Sager, 2007; Eling & Schmit, 2012).

Firm characteristics and market conditions

Table 4 reveals a significantly negative coefficient for the organizational form variable in the growth, profitability, and risk equations. Thus, stock insurers tend to grow, on average, faster than mutual insurers and also tend to be more profitable. The latter result is in line with the results in Leverty and Grace (2010), emphasizing the so-called expense preference hypothesis, which predicts that stock insurers are more efficient than mutual insurers (Cummins, Rubio-Misas, & Zi, 2004). Conversely, the results suggest that mutual insurers are less risky, which is in line with Lamm-Tennant and Starks (1993). Life insurers tend to grow faster than non-life insurers, but are, on average, less profitable. The first result reflects that European life insurers showed considerably higher average growth rates than non-life insurers in the pre-crisis period; by contrast, non-life insurers, on average, grew slightly more post-crisis (Swiss Re, 2014). Regarding the impact of firm size, smaller insurers tend to grow at a higher rate than larger ones. Larger companies tend to be more profitable. This finding is in line with the results in Leverty and Grace (2010), indicating that larger companies benefit from economies of scale (Biener, Eling, & Jia, 2017). However, larger insurers tend to be more risky (Table 4).

Higher interest rates and inflation decrease profitability and increase risk. The negative and significant coefficients of the penetration ratio in the profitability equations suggest that more developed and mature national insurance markets have lower profitability. The positive and significant coefficients of the penetration ratio in the risk equations suggest that these markets also have higher risks. These results could reflect the assumption of market structure theory that market power, which should be a more frequent occurrence in less developed markets, lowers risk, because firms have more control over prices to maintain profits (Hurdle, 1974).

4.2 Dynamic analysis

In a dynamic environment, firms may first choose to become successful in one performance dimension (e.g., high growth) and then thrive to also become successful in another dimension (e.g., profitability) (Davidsson et al., 2009). Thus, the non-linear growth impact on profitability in Table 4 may be driven by rapidly growing firms caring about profitability in the future. However, Davidsson et al. (2009) demonstrates that firms which first focus on growth more likely end up in the situation of both low growth and low profitability; by contrast, firms which first focus on profitability are more likely to reach the profitable growth state. We apply the analysis of Davidsson et al. (2009) to the European insurance sector and expand it to the safety-profitability and growth-safety dimensions. The results are reported in Table 7.

Panel A illustrates that insurers that initially focus on profitability (with low levels of growth) are more likely to reach a state of profitable growth, than insurers who initially focus on growth (at low levels of profitability); the results are stronger for shorter transition periods (i.e., left column of Table 7). Furthermore, insurers with a focus on growth are more likely to develop a situation of both low growth and low profitability; the only exception is the transition period of 2006–2013, in which a lower proportion of growth-firms transit to this group. This result emphasizes the robustness of Davidsson et al.'s (2009) result across industries. Thus, we conclude that the strategy of focusing first on high growth (e.g., M&A or looser underwriting discipline) and then obtain gains from financial synergies or price increases is, on average, less successful than focusing first on reaching high profitability and then increasing market share. The fact that the desired effects of high growth do not materialize may be due to the soaring costs after M&A or due to the long-term problems caused by a looser underwriting discipline.

Panel B illustrates that insurers that initially focus on profitability and do not consider safety, for the time being, more likely reach high safety levels in the future, instead of vice versa. One explanation for this result might be that superior profitability is based on a firm's competitive advantage, which secures stable economic rents that reduce profitability fluctuations (Davidsson et al., 2009). Regarding the likelihood to end up in the situation of low safety and low profitability, no clear trend for the two strategies can be noted. In some time periods, more safety-focused firms transit to this state; in other time periods, the converse is true.

Panel C illustrates that insurers that initially focus on high safety, on average, are more likely to record high growth over time and are less likely to end up in a situation of low growth and low safety. This result emphasizes that policyholders choose insurers with low risk levels (Zanjani, 2002; Epermanis & Harrington, 2006; Baranoff & Sager, 2007; Eling & Schmit, 2012). In addition, higher demand allows price increases to lead to improved profitability. By contrast, high growth firms less frequently reach high safety levels and more likely end in the situation of low growth and safety. This may be because high growth causes financial damage, especially in the future. For example, high growth due to a looser underwriting discipline may cause damage years after the business has been written, when claims are due and reserves are not sufficiently high or unexpected losses occur.

In addition to the regression results for H3a, the dynamic perspective reveals that focusing on growth and not considering safety more frequently leads to a situation of low growth and low safety. Thus, the problems (e.g., underserving and unexpected losses) of high growth (e.g., due to looser underwriting discipline) also emerge with a longer time horizon; for example, because of insufficient reserves (Barth & Eckles, 2009). A better strategy is to first focus on reducing the riskiness of the firm, which may then attract policyholders that value low-risk insurers, thus leading to firm growth.

Table 7 Non-parametric analysis results

Performance group	*Panel A: Growth and profitability*						*Panel B: Safety and profitability*						*Panel C: Growth and safety*					
Final	High growth, high profitability			Low growth, low profitability			High safety, high profitability			Low safety, low profitability			High growth, high safety			Low growth, low safety		
Initial High	Growth		Prof.	Growth		Prof.	Safety		Prof.	Safety		Prof.	Growth		Safety	Growth		Safety
Initial Low	Prof.	*z-test*	Growth	Prof.	*z-test*	Growth	Prof.	*z-test*	Safety	Prof.	*z-test*	Safety	Safety	*z-test*	Growth	Safety	*z-test*	Growth
2006–2013	6.604		7.767	5.189	***	9.709	3.731	**	8.759	4.104	*	7.664	11.297		8.120	10.460	**	5.556
2006–2012	11.792		13.592	14.151		11.650	14.493	*	17.059	18.841	***	7.647	8.333	*	13.362	13.426		11.207
2006–2011	8.491	***	15.534	21.226	***	12.136	9.701		20.438	12.687		10.584	15.063		17.094	15.900	***	8.547
2006-2010	11.321		16.019	15.094		12.621	10.145		17.647	26.570	***	3.529	11.111		15.517	9.259		13.793
2006–2009	13.679		14.078	18.396		14.078	6.344	***	14.964	8.209	***	16.058	9.205	***	17.949	16.318	***	8.974
2006–2008	6.604	***	16.505	18.396	**	11.650	11.594		10.588	12.560	***	0.000	8.796		10.345	16.204	***	8.190
2006–2007	9.434	***	22.816	26.415	***	8.252	5.599	***	11.314	6.343	***	14.599	7.113	***	22.650	23.431	***	8.120
Main conclusions	Firms more likely reach profitable growth if they initially prioritize profitability over growth.						Firms more likely reach profitability and safety if they initially prioritize profitability over safety.						Firms more likely reach safety and growth if they initially prioritize safety over growth.					

Notes: The table illustrates percentages of insurers that move from the initial performance group to the final performance group in the specified time period (Davidsson et al., 2009). For safety, the invers of the risk measure is used. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

4.3 Robustness tests

To test the robustness of our findings, we consider the following variations in the regression and dynamic analyses (Appendices K–S). The results are consistent with our core models, unless otherwise specified below.

We repeat the regression analyses by trimming at the 0.5th and 99.5th percentiles and at the 1.5th and 98.5th percentiles. Next, we use the change in net premiums written and the change in total assets (Hardwick & Adams, 2002) as alternative growth measures. We replace the equity value in Equation (5) with the total asset value to calculate the ROA before taxes (Pasiouras & Gaganis, 2013). We alter the time window to calculate the risk measures (moving standard deviation of annual firm profitability) and use five and six year periods of time. Lastly, we repeat the OLS estimation with year dummies per country.

In addition to minor deviations in the magnitude and significance, it is noteworthy that when using the trimming at the 0.5th and 99.5th percentiles, the quadratic growth term has a positive sign in the risk equation, as in the core model, but is insignificant (Appendix K). The impact of risk on profitability (H2a) cannot be confirmed when using five year periods of time for the alternative risk measure (Appendix P). In addition, when using six year periods of time for the alternative risk measure (Appendix Q), the linear growth term in the risk equation of Model (2) is negative but insignificant while the quadratic term is significantly positive as in the core model. These results occur because a longer time frame for calculating the risk measures leads to the exclusion of additional years from the sample, and thus, reduces the sample period. Nevertheless, all other results are consistent with our core models, demonstrating the robustness of our conclusions.

In addition to the evidence from the SEM for prospect theory (H2b), in Appendix S, we analyze whether firms that have high risk and low profitability levels (and are thus located on the left part of the curve in Appendix B) are likely to increase profitability and reduce risk over time. This analysis reveals that, although firms may increase their risk taking, because they show low profitability relative to a reference point, they are not more likely to reach a state of high profitability and low risk, as compared to firms with initial high profitability and high risk (i.e., firms located on the right tail of the curve in Appendix B). Moreover, these firms are more likely to persist at high risk and low profitability.

5 Conclusions

Our results reveal that the relationships among growth, profitability, and safety are reciprocal. We analyze these relationships using a new SEM with a sample of 1,988 European life and non-life insurers over eleven years. We also analyze the dynamic interactions of growth, profitability, and safety over time using the non-parametric approach developed by Davidsson et al. (2009). Our empirical results (Tables 4, 5, and 6) emphasize that, due to goal conflicts among growth, profitability, and safety, the three dimensions need to be jointly considered in a multi-period setup to comprehensively evaluate firm performance.

Extremely high growth is dangerous, reducing profitability and increasing risk, while firms that grow moderately are typically in a healthy situation in terms of profitability and risk. For financial services, underwriting and/or credit disciplines with careful risk screening and adequate risk premiums are the key for the desired state of profitable growth. Because of the two-folded impact of growth, regulators should pay additional attention to rapidly growing insurers. Our findings also emphasize that the aging phenomenon (D'Arcy & Gorvett, 2004) and inorganic growth (Cummins & Weiss, 2004) may be causes for profitability difficulties among rapidly growing firms. Consistent with our explanation, our results reveal that the majority of firms in our sample grow moderately; only a small portion of firms prioritize high growth over profitability and safety. In line with prospect theory, we find evidence that low profitability firms tend to be risk-seeking. The impact of risk on profitability is also two-folded: beyond a threshold, the positive impact diminishes and further risk increases reduce profitability, as Bowman (1982) discusses.

In the dynamic perspective, firms prioritizing profitability and safety over growth are more likely to reach profitable growth with safe operations, than firms that prioritize growth over profitability and safety. We also find that low profitability firms tend to be risk-seeking in the dynamic perspective. Moreover, we demonstrate that customers value the safety of financial services firms in the sense that safe firms attract more business over time.

The presented analyses offer various directions for future research. Our analysis could be expanded by considering the different sources of extremely high growth (e.g., inorganic vs. organic growth) and their moderating effects on profitability and safety. Alternative measures could be analyzed, such as embedded value measures for profitability, and liquidity measures to capture safety. The management of growth, profitability, and safety may also show different features for public and private firms, as well as for firms from matured and emerging markets. It would also be interesting to compare the results from the insurance industry to that of other financial services and manufacturing firms. On the methodological side, the interactions among growth, profitability, and safety could be further analyzed using a quantile regression approach (Sriram, Shi, & Ghosh, 2016), which takes the distributions of the three dimensions into account; thus, it could be a useful tool to obtain more insight about the tradeoffs.

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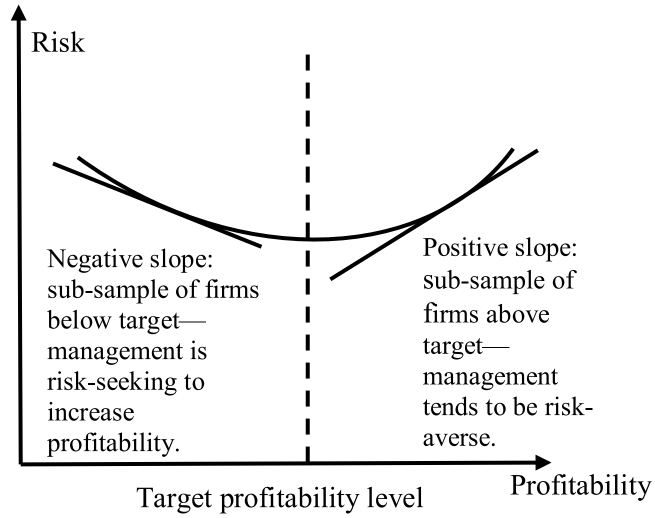
Appendix A

Reviewed studies for the theoretical background and hypotheses development

Paper	Firms / observations / geographic coverage / industry / period	Relevance for our paper
Andersen & Kheam (1998)	697 / NA / various industries / Norway / 1992	Theoretical linkage and exploratory study of resource-based theory and firm growth strategies
Baranoff & Sager (2007)	2,053 / NA / US / life insurance / 1994–2003	Empirical evidence for market discipline following rating downgrades and theoretic foundation for risk considerations of insures using inadequate pricing as growth strategy
Barth & Eckles (2004)	NA / approx. 24,000 / US / various insurance lines / 1990–2005	Theory and empirical evidence for the relation between firm growth and loss ratios
Biener et al. (2017)	116 / 843 / global / reinsurance / 2002–2012	Empirical evidence for the efficient structure hypothesis
Bowman (1982)	27 / NA / US / container industry / NA	Theoretical foundation for the risk-seeking behavior of relatively low profitability firms
Chang & Thomas (1989)	64 / NA / US / manufacturing / 1977–1981	Empirical evidence for a U-shaped profit-risk relationship
Cheng & Weiss (2012)	21,620 / 22,143 / US / property-liability insurance / 1994–2008	Empirical evidence for lower failure rates of larger insurers
Choi & Weiss (2005)	NA / 33,440 / US / property-liability insurance / 1992–1998	Empirical evidence for the relation between market structure and performance
Cummins & Rubio-Misas (2006)	382 / NA / Spain / all insurance lines / 1989–1998	Empirical evidence for the efficiency effects of consolidation
D'Arcy & Gorvett (2004)	15 / NA / US / property-liability insurance / 1990–2001	Illustration of profitability difficulties of insurers with high exposure growth
Davidsson et al. (2009)	A: 5,031 / NA / Australia / various industries / 1995–1998 B: 2,455 / NA / Sweden / various industries / 1997–2000	Theoretical framework for the growth-profitability relationships
Eisenhardt (1989)	Literature review	Review of agency theory and extant empirical evidence
Eling & Jia (2016)	3,078 / 21,308 / 28 countries / all insurance lines / 2003–2013	Empirical evidence for lower failure rates of larger insurers
Eling & Schmit (2012)	561 / 4,693 / Germany / various insurance lines / 1996–2005	Review of underwriting discipline and empirical evidence for market discipline (premium declines (or increased termination rates in life insurance)) following rating downgrades
Epermanis & Harrington (2006)	NA / 9,466 / US / property-casualty insurance / 1992–1999	Empirical evidence for market discipline following rating changes
Fairley (1979)	Theoretical paper	Illustration that rates of return on equity for property-liability insurers and underwriting profit margins are consistent with the CAPM
Fiegenbaum (1990)	Approx. 3,300 / NA / US / various industries / 1977–1984	Review of the implications of prospect theory at the organizational level
Fiegenbaum & Thomas (1988)	2,322 / NA / US / various industries / 1960–1979	Empirical evidence for prospect theory within and across industries as well as over time
Fok et al. (1997)	400 / NA / US / property-casualty insurance / 1991	Review for the expected positive impact of rapid firm growth on risk and empirical evidence for the impact of firm profitability on growth
Fuller & Jensen (2002)	Case study of two companies (energy and telecommunications)	Illustration of the perils of growth pressure
Greene & Segal (2004)	136 / 733 / US / life insurance / 1995–1998	Empirical evidence for the relation between cost (in)efficiency and profitability
Hardwick & Adams (2002)	176 / 1,076 / UK / life insurance / 1987–1996	Empirical evidence for the impact of firm profitability on growth
Hill (1979)	Theoretical paper	Application of the CAPM for estimating competitive profit rates of insurers
Jegers (1991)	Approx. 3,250 / NA / Belgium / manufacturing / 1977–1982	Review of the implications of prospect theory at the organizational level
Jia & Wu (2017)	A: Portfolio of group critical illness insurance, China, 2008–2013; B: Portfolio of loaner's personal accident insurance, China, 2008–2011	Charging prices below the technical price in the competition for customers causes profitability reductions
Kim et al. (1995)	164 / 878 / US / property-liability / 1984–1990; 75 / 280 / US / life insurance / 1987–1990	Review and empirical evidence for the expected positive impact of rapid firm growth on risk
Lawrence et al. (2006)	Case study (Telstra, Australia)	Review of the relationship between output prices and profitability
Mankaï & Belgacem (2016)	NA / 12,511 / US / property–liability insurance / 1999–2008	Implications of management's moral hazard for capital decisions
Nicholls-Nixon (2005)	Qualitative research	Discussion of performance considerations of high growth firms
Nickel & Rodriguez (2002)	Literature review	Review of the implications of prospect theory at the organizational level
Phillips et al. (1998)	71 / 315 / US / property-liability & multi-line insurance /1988–1992	Empirical evidence for the relation between firm risk and insurance prices
Ramezani et al. (2002)	2,156 / 23,720 / US / various industries / 1990–2000	Empirical evidence for the two-folded impact of firm growth on profitability
Rauch & Wende (2015)	NA / 863 / Germany / property-liability insurance / 2004–2011	Review and empirical evidence for the negative impact of aggressive firm growth on safety
Sharpe (1964)	Theoretical paper	Theoretical foundation of the CAPM
Sommer (1996)	142 / 1,420 / US / property-liability insurance / 1979–1989	Empirical evidence for the relation between firm risk and insurance prices
Wakker et al. (1997)	Survey / theoretical paper	Evidence for the premium reduction of increased default risk
Weiss & Choi (2008)	373 / 7,833 / US / automobile insurance / 1992–1998	Empirical evidence for the relation between market structure and performance
Whittington (1980)	735 / 11,025 / UK / various industries / 1960–1974	Empirical analysis of the relationship between the profitability and size
Williamson (1966)	Theoretical paper	Discussion of performance considerations of high growth firms
Yuengert (1993)	765 / NA / US / life insurance / 1989	Empirical evidence for scale economies
Zanjani (2002)	756 / 7,507 / US / life insurance / 1988–1998	Empirical evidence for market discipline
Zhang & Nielson (2015)	2,163 / 15,645 / US / property-casualty insurance / 1996–2006	Empirical evidence for financial trouble of insurers that grow too quickly

Appendix B

Profitability-risk relationship (Nickel & Rodriguez, 2002)



Appendix C

2SLS estimation following Wooldridge (2010, pp. 209 ff.)

$Growth = G, Profitability = P, Risk = R$

Second-stage regressions Model (1):

$$G_{i,t} = \gamma_{1,1}\hat{P}_{i,t} + \gamma_{1,2}\hat{R}_{i,t} + \gamma_{1,3}Organizational\ form_{i,t} + \gamma_{1,4}Line\ of\ business + \gamma_{1,5}\ ln(Firm\ size)_{i,t-1} + \gamma_{1,6}Industry\ growth_{i,t} + \gamma_{1,7}GDP\ growth_{i,t} + \gamma_{1,8}Longterm\ interest\ rate_{i,t} + \gamma_{1,9}Inflation_{i,t} + \gamma_{1,10}Concentration\ ratio_{i,t} + \gamma_{1,11}Penetration\ ratio_{i,t} + \varepsilon_{i,t} \quad (A1)$$

$$P_{i,t} = \gamma_{2,1}\hat{G}_{i,t} + \gamma_{2,2}\hat{R} + \gamma_{2,3}P_{i,t-1} + \gamma_{2,4}Organizational\ form_{i,t} + \gamma_{2,5}Line\ of\ business + \gamma_{2,6}\ ln(Firm\ size)_{i,t-1} + \gamma_{2,7}GDP\ growth_{i,t} + \gamma_{2,8}Longterm\ interest\ rate_{i,t} + \gamma_{2,9}Inflation_{i,t} + \gamma_{2,10}Concentration\ ratio_{i,t} + \gamma_{2,11}Penetration\ ratio_{i,t} + \omega_{i,t} \quad (A2)$$

$$R_{i,t} = \gamma_{3,1}\hat{P}_{i,t} + \gamma_{3,2}\hat{G}_{i,t} + \gamma_{3,3}R_{i,t-1} + \gamma_{3,4}Organizational\ form_{i,t} + \gamma_{3,5}Line\ of\ business + \gamma_{3,6}\ ln(Firm\ size)_{i,t-1} + \gamma_{3,7}GDP\ growth_{i,t} + \gamma_{3,8}Longterm\ interest\ rate_{i,t} + \gamma_{3,9}Inflation_{i,t} + \gamma_{3,10}Concentration\ ratio_{i,t} + \gamma_{3,11}Penetration\ ratio_{i,t} + \vartheta_{i,t} \quad (A3)$$

Second-stage regressions Model (2):

$$G_{i,t} = \gamma_{1,1}\hat{P}_{i,t} + \gamma_{1,2}\hat{\hat{P}}^2_{i,t} + \gamma_{1,3}\hat{R}_{i,t} + \gamma_{1,4}\hat{\hat{R}}^2_{i,t} + \gamma_{1,5}Organizational\ form_{i,t} + \gamma_{1,6}Line\ of\ business + \gamma_{1,7}\ ln(Firm\ size)_{i,t-1} + \gamma_{1,8}Industry\ growth_{i,t} + \gamma_{1,9}GDP\ growth_{i,t} + \gamma_{1,10}Longterm\ interest\ rate_{i,t} + \gamma_{1,11}Inflation_{i,t} + \gamma_{1,12}Concentration\ ratio_{i,t} + \gamma_{1,13}Penetration\ ratio_{i,t} + \varepsilon_{i,t} \quad (A4)$$

$$P_{i,t} = \gamma_{2,1}\hat{G}_{i,t} + \gamma_{2,2}\hat{\hat{G}}^2_{i,t} + \gamma_{2,3}\hat{R} + \gamma_{2,4}\hat{\hat{R}}^2_{i,t} + \gamma_{2,5}P_{i,t-1} + \gamma_{2,6}Organizational\ form_{i,t} + \gamma_{2,7}Line\ of\ business + \gamma_{2,8}\ ln(Firm\ size)_{i,t-1} + \gamma_{2,9}GDP\ growth_{i,t} + \gamma_{2,10}Longterm\ interest\ rate_{i,t} + \gamma_{2,11}Inflation_{i,t} + \gamma_{2,12}Concentration\ ratio_{i,t} + \gamma_{2,13}Penetration\ ratio_{i,t} + \omega_{i,t} \quad (A5)$$

$$R_{i,t} = \gamma_{3,1}\hat{P}_{i,t} + \gamma_{3,2}\hat{\hat{P}}^2_{i,t} + \gamma_{3,3}\hat{G}_{i,t} + \gamma_{3,4}\hat{\hat{G}}^2_{i,t} + \gamma_{3,5}R_{i,t-1} + \gamma_{3,6}Organizational\ form_{i,t} + \gamma_{3,7}Line\ of\ business + \gamma_{3,8}\ ln(Firm\ size)_{i,t-1} + \gamma_{3,9}GDP\ growth_{i,t} + \gamma_{3,10}Longterm\ interest\ rate_{i,t} + \gamma_{3,11}Inflation_{i,t} + \gamma_{3,12}Concentration\ ratio_{i,t} + \gamma_{3,13}Penetration\ ratio_{i,t} + \vartheta_{i,t} \quad (A6)$$

1a) First-stage regressions to estimate coefficients to obtain fitted linear terms:

$$G_{i,t} = \delta_{1,1}P_{i,t-1} + \delta_{1,2}R_{i,t-1} + \delta_{1,3}Organizational\ form_{i,t} + \delta_{1,4}Line\ of\ business_{i,t} + \delta_{1,5}\ ln(Firm\ size)_{i,t-1} + \delta_{1,6}Industry\ growth_{i,t} + \delta_{1,7}GDP\ growth_{i,t} + \delta_{1,8}Longterm\ interest\ rate_{i,t} + \delta_{1,9}Inflation_{i,t} + \delta_{1,10}Concentration\ ratio_{i,t} + \delta_{1,11}Penetration\ ratio_{i,t} + \varepsilon_{i,t} \quad (A7)$$

$$P_{i,t} = \delta_{2,1}P_{i,t-1} + \delta_{2,2}R_{i,t-1} + \delta_{2,3}Organizational\ form_{i,t} + \delta_{2,4}Line\ of\ business_{i,t} + \delta_{2,5}\ ln(Firm\ size)_{i,t-1} + \delta_{2,6}Industry\ growth_{i,t} + \delta_{2,7}GDP\ growth_{i,t} + \delta_{2,8}Longterm\ interest\ rate_{i,t} + \delta_{2,9}Inflation_{i,t} + \delta_{2,10}Concentration\ ratio_{i,t} + \delta_{2,11}Penetration\ ratio_{i,t} + \omega_{i,t} \quad (A8)$$

$$R_{i,t} = \delta_{3,1}P_{i,t-1} + \delta_{3,2}R_{i,t-1} + \delta_{3,3}Organizational\ form_{i,t} + \delta_{3,4}Line\ of\ business_{i,t} + \delta_{3,5}\ ln(Firm\ size)_{i,t-1} + \delta_{3,6}Industry\ growth_{i,t} + \delta_{3,7}GDP\ growth_{i,t} + \delta_{3,8}Longterm\ interest\ rate_{i,t} + \delta_{3,9}Inflation_{i,t} + \delta_{3,10}Concentration\ ratio_{i,t} + \delta_{3,11}Penetration\ ratio_{i,t} + \vartheta_{i,t} \quad (A9)$$

1b) Insertion of estimated coefficients from 1a) and observed values of right-hand side variables to obtain fitted linear terms:

$$\hat{G}_{i,t} = \hat{\delta}_{1,1}P_{i,t-1} + \hat{\delta}_{1,2}R_{i,t-1} + \hat{\delta}_{1,3}Organizational\ form_{i,t} + \hat{\delta}_{1,4}Line\ of\ business_{i,t} + \hat{\delta}_{1,5}\ ln(Firm\ size)_{i,t-1} + \hat{\delta}_{1,6}Industry\ growth_{i,t} + \hat{\delta}_{1,7}GDP\ growth_{i,t} + \hat{\delta}_{1,8}Longterm\ interest\ rate_{i,t} + \hat{\delta}_{1,9}Inflation_{i,t} + \hat{\delta}_{1,10}Concentration\ ratio_{i,t} + \hat{\delta}_{1,11}Penetration\ ratio_{i,t} \quad (A10)$$

$$\hat{P}_{i,t} = \hat{\delta}_{2,1}P_{i,t-1} + \hat{\delta}_{2,2}R_{i,t-1} + \hat{\delta}_{2,3}Organizational\ form_{i,t} + \hat{\delta}_{2,4}Line\ of\ business_{i,t} + \hat{\delta}_{2,5}\ ln(Firm\ size)_{i,t-1} + \hat{\delta}_{2,6}Industry\ growth_{i,t} + \hat{\delta}_{2,7}GDP\ growth_{i,t} + \hat{\delta}_{2,8}Longterm\ interest\ rate_{i,t} + \hat{\delta}_{2,9}Inflation_{i,t} + \hat{\delta}_{2,10}Concentration\ ratio_{i,t} + \hat{\delta}_{2,11}Penetration\ ratio_{i,t} \quad (A11)$$

$$\hat{R}_{i,t} = \hat{\delta}_{3,1}P_{i,t-1} + \hat{\delta}_{3,2}R_{i,t-1} + \hat{\delta}_{3,3}Organizational\ form_{i,t} + \hat{\delta}_{3,4}Line\ of\ business_{i,t} + \hat{\delta}_{3,5}\ ln(Firm\ size)_{i,t-1} + \hat{\delta}_{3,6}Industry\ growth_{i,t} + \hat{\delta}_{3,7}GDP\ growth_{i,t} + \hat{\delta}_{3,8}Longterm\ interest\ rate_{i,t} + \hat{\delta}_{3,9}Inflation_{i,t} + \hat{\delta}_{3,10}Concentration\ ratio_{i,t} + \hat{\delta}_{3,11}Penetration\ ratio_{i,t} \quad (A12)$$

2a) First-stage regressions to estimate coefficients to obtain fitted non-linear terms:

$$G^2_{i,t} = \rho_1\hat{G}^2_{i,t} + \varepsilon_{i,t} \quad (A13)$$

$$P^2_{i,t} = \rho_2\hat{P}^2_{i,t} + \omega_{i,t} \quad (A14)$$

$$R^2_{i,t} = \rho_3\hat{R}^2_{i,t} + \vartheta_{i,t} \quad (A15)$$

2b) Insertion of estimated coefficients from 2a) to obtain fitted non-linear terms:

$$\hat{\hat{G}}^2_{i,t} = \hat{\rho}_1\hat{G}^2_{i,t} \quad (A16)$$

$$\hat{\hat{P}}^2_{i,t} = \hat{\rho}_2\hat{P}^2_{i,t} \quad (A17)$$

$$\hat{\hat{R}}^2_{i,t} = \hat{\rho}_3\hat{R}^2_{i,t} \quad (A18)$$

Appendix D

First-stage regressions results

	Appendix G: 1a)			Appendix G: 2b)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Industry growth	0.994*** (0.026)	0.208*** (0.017)	-0.045*** (0.007)			
$Profitability_{t-1}$	0.012 (0.014)	0.469*** (0.009)	-0.022*** (0.004)			
$Risk_{t-1}$	-0.004 (0.022)	0.137*** (0.014)	0.750*** (0.006)			
Organizational form (mutual=1, stock=0)	-0.030*** (0.006)	-0.030*** (0.004)	-0.002 (0.002)			
Line of business (life=1, non-life=0)	0.015** (0.006)	-0.009** (0.004)	-0.002 (0.001)			
$Ln(Firm\ size)_{t-1}$	-0.006*** (0.001)	0.003*** (0.001)	0.001** (0.0003)			
GDP growth	-0.011 (0.107)	-0.163** (0.069)	-0.220*** (0.027)			
Long-term interest rate	-0.220 (0.184)	-0.265** (0.119)	0.215*** (0.047)			
Inflation	-0.042 (0.227)	-0.788*** (0.146)	0.290*** (0.058)			
Concentration ratio	0.008 (0.017)	-0.012 (0.011)	0.007 (0.004)			
Penetration ratio	-0.006 (0.120)	-0.189** (0.078)	0.125*** (0.031)			
$\hat{G}^2$				2.096*** (0.079)		
$\hat{P}^2$					1.382*** (0.025)	
$\hat{R}^2$						1.135*** (0.008)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.262	0.159	0.671	0.252	0.071	0.669
F Statistic	161***	301.***	1,726***	706***	3,129***	18,828***
F-test for weak instruments	1,501***	2,562***	17,856***			

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. A constant term is included, but not reported. Growth=G, Profitability=P, Risk=R. The F-tests for weak instruments reject the null hypothesis of the existence of weak instruments, supporting the choice of instruments (i.e., industry levels, lagged values of growth, profitability, risk).

Appendix E

Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Growth	1													
2. Profitability	0.092	1												
3. Risk	-0.021	-0.065	1											
4. Organizational form (mutual=1, stock=0)	-0.038	-0.125	0.001	1										
5. Line of business (life=1, non-life=0)	0.019	-0.018	0.062	0.016	1									
6. Firm size	-0.001	0.036	0.018	-0.070	0.246	1								
7. Industry growth	0.394	0.156	-0.036	0.004	0.049	0.015	1							
8. Industry profitability	0.169	0.365	-0.098	-0.033	-0.049	-0.017	0.428	1						
9. Industry risk	-0.036	-0.090	0.397	0.024	0.157	0.048	-0.091	-0.247	1					
10. GDP growth	0.076	0.068	-0.054	0.003	0.030	0.010	0.192	0.186	-0.136	1				
11. Long-term interest rate	-0.027	-0.019	0.043	-0.104	-0.033	-0.083	-0.069	-0.053	0.109	-0.046	1			
12. Inflation	0.018	-0.003	0.118	0.034	0.068	-0.003	0.045	-0.010	0.296	-0.047	0.060	1		
13. Concentration ratio	-0.079	-0.057	0.044	-0.003	-0.022	-0.016	-0.200	-0.156	0.110	0.319	0.212	-0.050	1	
14. Penetration ratio	0.024	-0.002	0.099	-0.019	0.271	0.131	0.062	-0.006	0.248	0.022	-0.081	0.118	-0.037	1

Appendix F

2SLS regression results in two risk quantile

	High risk quantile: Solvency measure <=50% quantile		Low risk quantile: Solvency measure >50% quantile	
	Growth	Profitability	Growth	Profitability
Growth		0.239*** (0.027)		0.200*** (0.027)
Growth^2		-0.046*** (0.167)		-0.036** (0.017)
Profitability	0.096 (0.074)		-0.080 (0.074)	
Profitability^2	-0.300*** (0.103)		0.033 (0.103)	
Industry growth	0.976*** (0.086)		1.030*** (0.086)	
Profitability$_{t-1}$		0.418*** (0.030)		0.538*** (0.030)
Organizational form (mutual=1, stock=0)	-0.055*** (0.012)	-0.023*** (0.006)	-0.040*** (0.012)	-0.020*** (0.006)
Line of business (life=1, non-life=0)	0.023 (0.014)	-0.019*** (0.007)	0.048*** (0.014)	-0.028*** (0.007)
Ln(Firm size)$_{t-1}$	-0.019 (0.004)	0.008*** (0.002)	-0.004 (0.004)	0.003 (0.002)
GDP growth	-0.035 (0.244)	-0.088 (0.120)	0.017 (0.244)	-0.247** (0.120)
Long-term interest rate	-0.254 (0.394)	-0.348* (0.194)	-0.360 (0.393)	0.168 (0.197)
Inflation	0.043 (0.551)	-0.902*** (0.291)	-0.155 (0.552)	-0.627** (0.292)
Concentration ratio	0.020 (0.034)	0.007 (0.021)	0.003 (0.034)	0.006 (0.021)
Penetration ratio	0.151 (0.286)	-0.175 (0.150)	-0.037 (0.287)	-0.005 (0.151)
Number of firms	1,099	1,099	1,183	1,183
Observations	4,800	4,800	4,800	4,800
Adjusted R^2	0.115	0.214	0.142	0.327
F Statistic	24***	48***	24***	46***

Notes: The complete sample is split into two subsamples based on the 50%-quantile of a solvency measure (i.e., capital and surplus to total assets) to analyze the links between growth and profitability based on a 2SLS estimation in more homogenous safety groups. Thus, we are able to omit the risk measure from the explanatory variables. ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included but not reported.

Appendix G

2SLS regression results with country dummies and year dummies

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.050^{**} (0.022)	0.007 (0.009)		0.033 (0.026)	0.004 (0.010)
$Growth^2$					0.022 (0.020)	0.005 (0.008)
Profitability	0.027 (0.030)		-0.047^{***} (0.008)	-0.048 (0.053)		-0.120^{***} (0.013)
$Profitability^2$				0.195^{*} (0.116)		0.199^{***} (0.029)
Risk	-0.011 (0.030)	0.181^{***} (0.019)		0.060 (0.079)	0.311^{***} (0.048)	
$Risk^2$				-0.183 (0.143)	-0.265^{***} (0.090)	
Industry growth	0.999^{***} (0.035)			0.999^{***} (0.035)		
$Profitability_{t-1}$		0.479^{***} (0.009)			0.477^{***} (0.009)	
$Risk_{t-1}$			0.752^{***} (0.006)			0.737^{***} (0.006)
Organizational form (mutual=1, stock=0)	-0.031^{***} (0.006)	-0.024^{***} (0.004)	-0.003^{**} (0.002)	-0.030^{***} (0.006)	-0.024^{***} (0.004)	-0.003^{**} (0.002)
Line of business (life=1, non-life=0)	0.016^{**} (0.007)	-0.019^{***} (0.004)	0.001 (0.002)	0.016^{**} (0.007)	-0.018^{***} (0.004)	0.001 (0.002)
$Ln(Firm\ size)_{t-1}$	-0.007^{***} (0.001)	0.005^{***} (0.001)	0.001^{*} (0.0003)	-0.007^{***} (0.001)	0.005^{***} (0.001)	0.001^{**} (0.0003)
GDP growth	-0.016 (0.258)	0.149 (0.162)	0.002 (0.065)	-0.023 (0.258)	0.153 (0.162)	-0.004 (0.065)
Long-term interest rate	-0.030 (0.315)	0.115 (0.199)	0.224^{***} (0.079)	-0.059 (0.316)	0.064 (0.200)	0.206^{***} (0.079)
Inflation	-0.054 (0.344)	0.431^{**} (0.216)	0.254^{***} (0.086)	-0.058 (0.343)	0.418^{*} (0.216)	0.250^{***} (0.086)
Concentration ratio	-0.010 (0.041)	0.156^{***} (0.026)	-0.049^{***} (0.010)	-0.012 (0.041)	0.155^{***} (0.026)	-0.049^{***} (0.010)
Penetration ratio	0.010 (0.161)	-0.243^{**} (0.101)	0.036 (0.040)	0.013 (0.161)	-0.241^{**} (0.101)	0.035 (0.040)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.157	0.299	0.683	0.158	0.299	0.685
F Statistic	29^{***}	70^{***}	282^{***}	28^{***}	66^{***}	280^{***}
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported. Growth=G, Profitability=P, Risk=R.

Appendix H
VIF comparison

2SLS VIF not considering country and year dummies in first- and second-stage regressions						
	Model (1) Equation (4)	Model (1) Equation (5)	Model (1) Equation (6)	Model (2) Equation (4)	Model (2) Equation (5)	Model (2) Equation (6)
Growth		1.18	1.29		1.67	1.80
$Growth^2$					1.46	1.48
Profitability	1.26		1.30	4.26		4.28
$Profitability^2$				4.29		4.35
Risk	1.07	1.05		7.27	6.99	
$Risk^2$				6.87	6.87	
Average VIF	1.20	1.17	1.21	2.58	2.14	1.76

2SLS VIF considering country and year dummies in first- and second-stage regressions						
	Model (1) Equation (4)	Model (1) Equation (5)	Model (1) Equation (6)	Model (2) Equation (4)	Model (2) Equation (5)	Model (2) Equation (6)
Growth		2.14	2.15		3.07	3.09
$Growth^2$					1.94	1.94
Profitability	1.46		1.49	4.42		4.38
$Profitability^2$				3.95		3.94
Risk	1.17	1.15		7.79	7.46	
$Risk^2$				7.12	7.11	
Average VIF	4.29	4.03	4.19	4.93	4.83	5.03

OLS VIF not considering country and year dummies						
	Model (1) Equation (4)	Model (1) Equation (5)	Model (1) Equation (6)	Model (2) Equation (4)	Model (2) Equation (5)	Model (2) Equation (6)
Growth		1.03	1.03		1.97	1.99
$Growth^2$					1.94	1.95
Profitability	1.06			1.46		1.36
$Profitability^2$				1.59		1.40
Risk	1.04	1.03	1.05	5.92	5.66	
$Risk^2$				5.61	5.61	
Average VIF	1.16	1.14	1.13	1.94	1.98	1.32

OLS VIF considering country and year dummies						
	Model (1) Equation (4)	Model (1) Equation (5)	Model (1) Equation (6)	Model (2) Equation (4)	Model (2) Equation (5)	Model (2) Equation (6)
Growth		1.09	1.10		2.16	2.17
$Growth^2$					2.04	2.04
Profitability	1.10		1.11	1.50		1.42
$Profitability^2$				1.60		1.41
Risk	1.09	1.10		6.14	5.87	
$Risk^2$				5.72	5.71	
Average VIF	3.99	3.39	3.40	4.17	3.67	3.40

Appendix I

Granger causality tests

Hypotheses to be tested	n=1	n=2	n=3	n=4	n=5	n=6
	p-values of nested F-test					
Growth and profitability	0.293	0.619	0.229	0.001	0.000	0.120
H.A_0: Profitability does not Granger cause growth	0.001	0.000	0.000	0.037	0.095	0.076
H.B_0: Growth does not Granger cause profitability						
Safety and profitability						
H.C_0: Risk does not Granger cause profitability	0.000	0.000	0.000	0.000	0.000	0.000
H.D_0: Profitability does not Granger cause risk	0.137	0.443	0.035	0.000	0.000	0.000
Growth and safety						
H.E_0: Growth does not Granger cause risk	0.484	0.000	0.025	0.222	0.671	0.851
H.F_0: Risk does not Granger cause growth	0.403	0.457	0.039	0.339	0.179	0.608
Number of observations	7,146	5,343	3,992	2,942	2,005	1,156

Notes: n denotes the number of lagged variables considered in the testing procedure. With Equation (A1), we test the null hypothesis that profitability does not Granger cause growth (H.A_0)—namely, $\alpha_{1,1} = \alpha_{1,2} = \cdots = \alpha_{1,n} = 0$. With Equation (A2), we test the null hypotheses of no reverse causality (H.B_0)—namely, that growth does not Granger cause profitability ($\beta_{2,1} = \cdots = \beta_{2,n} = 0$). If both null hypotheses are rejected (i.e., profitability is Granger causing growth and vice versa), feedback among profitability and growth is occurring, indicating a reciprocal relationship.

$$Growth_{i,t} = \alpha_0 + \sum \alpha_{1,n} Profitability_{i,t-n} + \sum \alpha_{2,n} Growth_{i,t-n} + u_{i,t} \tag{A1}$$

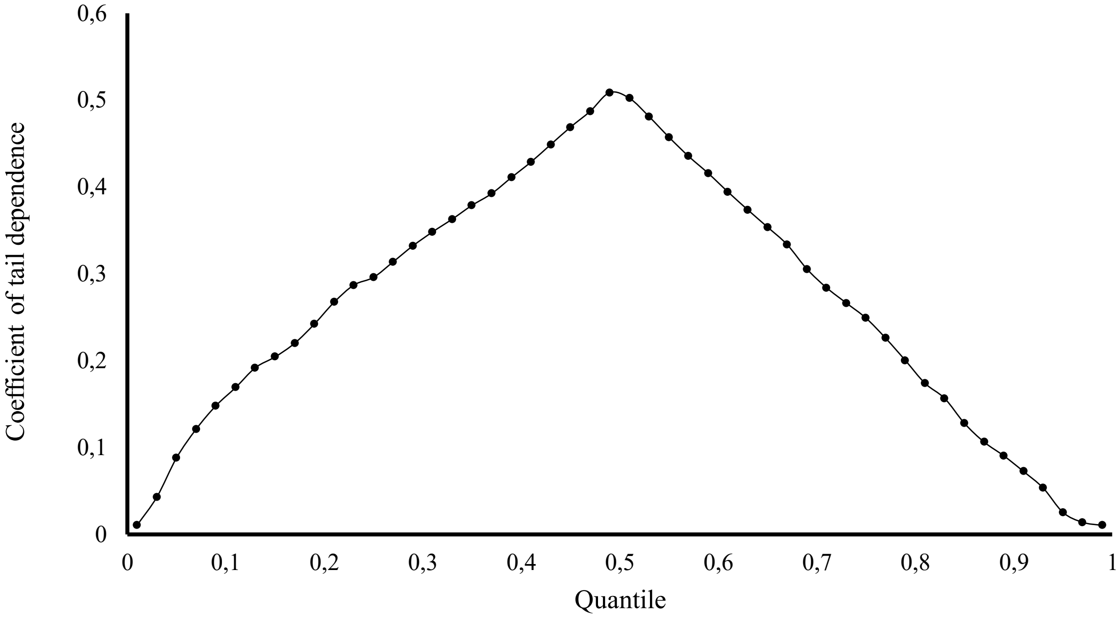
$$Profitability_{i,t} = \beta_0 + \sum \beta_{1,n} Profitability_{i,t-n} + \sum \beta_{2,n} Growth_{i,t-n} + v_{i,t} \tag{A2}$$

Using the same logic of Equations (A1) and (A2), we also specify equations and test for causality among the safety-profitability (i.e., H.C_0: safety does not Granger cause profitability; H.D_0: profitability does not Granger cause safety) and growth-safety (i.e., H.E_0: growth does not Granger cause safety; H.F_0: safety does not Granger cause growth) dimensions. All equations are estimated by gradually including additional lags until the maximum number of lags in our sample is reached (i.e., n=1, 2, …, 6), and the null hypotheses are tested by nested F-tests.

Appendix I reveals that firm growth Granger causes profitability if up to three lagged variables are considered. However, if four and five lagged variables are considered, the F-test is also significant in (A2). Thus, it is reasonable to conclude that feedback among growth and profitability occurs, as both H.A_0 and H.B_0 are rejected depending on the number of lagged variables considered. The same conclusion can be drawn for safety and profitability: both H.C_0 and H.D_0 are rejected in four of the six model specifications presented in Appendix I. Similarly, H.E_0 and H.F_0 are both rejected if three lagged variables are considered. Thus, the results support the view that feedback (i.e., reciprocal causation) among growth, profitability, and safety occurs (see Section 2).

Appendix J

Tail dependence between firm risk and growth



Notes: We calculate the tail dependence between firm risk and growth following Patton (2012). We use the inverse of the firm risk measure in Equation (3) to test the hypothesis that relatively low or even negative growth is especially sensitive to high firm risk as documented in the literature (see, e.g., Eling & Schmit, 2012). Thus, we analyzes whether firms that appear in the left-tail of the distribution of the inverse risk measure (i.e., relatively high risk firms) also appear in the left-tail of the distribution of the growth measure (i.e., relatively more negative firm growth). According to the figure, there exists a stronger dependence between the left-tails than for the right tails of the growth and risk distributions. For example, the tail dependence for the 10th percentile is approximately 0.15 vs. 0.07 for the 90th percentile.

Appendix K

Alternative trimming (99.5% and 0.5% percentiles)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.153*** (0.038)	-0.024** (0.010)		0.213*** (0.017)	-0.038*** (0.007)
Growth^2					-0.037*** (0.003)	0.001 (0.002)
Profitability	-0.058 (0.042)		-0.050*** (0.011)	0.005 (0.058)		-0.181*** (0.021)
Profitability^2				-0.161 (0.115)		0.337*** (0.050)
Risk	-0.004 (0.040)	0.166*** (0.027)		0.031 (0.090)	0.328*** (0.054)	
Risk^2				-0.024 (0.120)	-0.267*** (0.095)	
Industry growth	1.005*** (0.050)			1.011*** (0.052)		
Profitability$_{t-1}$		0.472*** (0.021)			0.471*** (0.021)	
Risk$_{t-1}$			0.750*** (0.015)			0.717*** (0.017)
Organizational form (mutual=1, stock=0)	-0.050*** (0.008)	-0.025*** (0.004)	-0.004** (0.002)	-0.050*** (0.008)	-0.022*** (0.004)	-0.005*** (0.002)
Line of business (life=1, non-life=0)	0.022** (0.011)	-0.014*** (0.004)	-0.002 (0.002)	0.022** (0.011)	-0.014*** (0.004)	-0.002 (0.001)
Ln(Firm size)$_{t-1}$	-0.010*** (0.002)	0.004*** (0.001)	0.0004 (0.0003)	-0.010*** (0.002)	0.005*** (0.001)	0.0005 (0.0003)
GDP growth	0.029 (0.164)	-0.076 (0.086)	-0.234*** (0.033)	0.021 (0.165)	-0.109 (0.077)	-0.202*** (0.032)
Long-term interest rate	-0.337 (0.251)	-0.192 (0.129)	0.219*** (0.051)	-0.325 (0.253)	-0.183 (0.130)	0.172*** (0.048)
Inflation	-0.098 (0.342)	-0.981*** (0.196)	0.241*** (0.067)	-0.090 (0.345)	-0.888*** (0.173)	0.203*** (0.062)
Concentration ratio	0.014 (0.021)	-0.010 (0.013)	0.009** (0.005)	0.013 (0.021)	-0.016 (0.013)	0.012** (0.005)
Penetration ratio	0.0004 (0.172)	-0.171* (0.091)	0.069* (0.036)	-0.00002 (0.172)	-0.166* (0.091)	0.066* (0.034)
Observations	9,599	9,599	9,599	9,599	9,599	9,599
Number of firms	2,017	2,017	2,017	2,017	2,017	2,017
Adjusted R^2	0.126	0.259	0.677	0.126	0.264	0.683
F Statistic	52***	88***	346***	46***	98***	386***
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix L

Alternative trimming (98.5% and 1.5% percentiles)

		Model (1)			Model (2)	
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.220*** (0.019)	-0.038*** (0.007)		0.248*** (0.022)	-0.069*** (0.009)
Growth^2					-0.074* (0.043)	0.081*** (0.014)
Profitability	-0.009 (0.033)		-0.036*** (0.008)	-0.021 (0.059)		-0.148*** (0.017)
Profitability^2				0.032 (0.139)		0.330*** (0.048)
Risk	-0.007 (0.037)	0.164*** (0.024)		0.048 (0.095)	0.416*** (0.064)	
Risk^2				-0.136 (0.218)	-0.595*** (0.153)	
Industry growth	0.998*** (0.044)			0.998*** (0.044)		
Profitability$_{t-1}$		0.495*** (0.017)			0.493*** (0.017)	
Risk$_{t-1}$			0.742*** (0.009)			0.724*** (0.009)
Organizational form (mutual=1, stock=0)	-0.027*** (0.005)	-0.020*** (0.003)	-0.004*** (0.001)	-0.027*** (0.005)	-0.019*** (0.003)	-0.004*** (0.001)
Line of business (life=1, non-life=0)	0.012* (0.006)	-0.008** (0.004)	-0.002** (0.001)	0.012* (0.006)	-0.005 (0.004)	-0.003*** (0.001)
Ln(Firm size)$_{t-1}$	-0.005*** (0.001)	0.003*** (0.001)	0.0004 (0.0002)	-0.005*** (0.001)	0.003*** (0.001)	0.0004 (0.0002)
GDP growth	0.008 (0.105)	-0.155** (0.070)	-0.217*** (0.026)	0.013 (0.105)	-0.149** (0.070)	-0.192*** (0.025)
Long-term interest rate	-0.188 (0.183)	-0.258** (0.110)	0.184*** (0.043)	-0.201 (0.183)	-0.263** (0.114)	0.117*** (0.042)
Inflation	-0.042 (0.246)	-0.695*** (0.163)	0.194*** (0.053)	-0.051 (0.246)	-0.689*** (0.165)	0.143*** (0.052)
Concentration ratio	0.008 (0.016)	-0.015 (0.011)	0.006 (0.004)	0.007 (0.017)	-0.020* (0.011)	0.006 (0.004)
Penetration ratio	-0.007 (0.140)	-0.203*** (0.078)	0.101*** (0.028)	-0.011 (0.139)	-0.218*** (0.077)	0.093*** (0.028)
Observations	8,955	8,955	8,955	8,955	8,955	8,955
Number of firms	1,953	1,953	1,953	1,953	1,953	1,953
Adjusted R^2	0.180	0.290	0.654	0.179	0.292	0.658
F Statistic	80***	166***	771***	68***	148***	702***
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix M

Alternative growth measure (change in net premiums written)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.202*** (0.018)	-0.031*** (0.007)		0.235*** (0.020)	-0.047*** (0.009)
$Growth^2$					-0.049*** (0.014)	0.021** (0.010)
Profitability	-0.053 (0.047)		-0.047*** (0.009)	-0.078 (0.090)		-0.168*** (0.018)
$Profitability^2$				0.054 (0.189)		0.334*** (0.047)
Risk	0.011 (0.038)	0.181*** (0.023)		0.183* (0.101)	0.279*** (0.053)	
$Risk^2$				-0.363** (0.179)	-0.202* (0.105)	
Industry growth	1.007*** (0.071)			1.007*** (0.071)		
$Profitability_{t-1}$		0.480*** (0.018)			0.478*** (0.019)	
$Risk_{t-1}$			0.756*** (0.010)			0.733*** (0.010)
Organizational form (mutual=1, stock=0)	-0.042*** (0.007)	-0.021*** (0.003)	-0.004*** (0.002)	-0.042*** (0.007)	-0.020*** (0.003)	-0.004*** (0.002)
Line of business (life=1, non-life=0)	0.016* (0.009)	-0.012*** (0.004)	-0.002 (0.001)	0.017* (0.009)	-0.011*** (0.004)	-0.002* (0.001)
$Ln(Firm\ size)_{t-1}$	-0.007*** (0.002)	0.004*** (0.001)	0.001** (0.0003)	-0.007*** (0.002)	0.004*** (0.001)	0.001** (0.0003)
GDP growth	0.026 (0.149)	-0.125* (0.075)	-0.226*** (0.028)	0.045 (0.150)	-0.141* (0.075)	-0.202*** (0.027)
Long-term interest rate	-0.276 (0.234)	-0.274** (0.117)	0.201*** (0.047)	-0.319 (0.237)	-0.256** (0.118)	0.157*** (0.046)
Inflation	-0.080 (0.353)	-0.869*** (0.165)	0.262*** (0.057)	-0.113 (0.354)	-0.840*** (0.165)	0.234*** (0.057)
Concentration ratio	0.009 (0.021)	-0.014 (0.012)	0.007 (0.004)	0.005 (0.021)	-0.016 (0.012)	0.007* (0.004)
Penetration ratio	-0.021 (0.178)	-0.183** (0.083)	0.114*** (0.030)	-0.033 (0.178)	-0.186** (0.084)	0.107*** (0.030)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.117	0.262	0.671	0.117	0.263	0.676
F Statistic	37***	129***	653***	33***	114***	627***
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix N

Alternative growth measure (change in assets)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.345*** (0.021)	-0.063*** (0.009)		0.415*** (0.031)	-0.088*** (0.013)
Growth^2					-0.282*** (0.087)	0.106*** (0.037)
Profitability	0.063*** (0.024)		-0.043*** (0.009)	0.069* (0.038)		-0.136*** (0.019)
Profitability^2				-0.023 (0.090)		0.255*** (0.047)
Risk	0.012 (0.022)	0.160*** (0.024)		0.082 (0.055)	0.271*** (0.053)	
Risk^2				-0.139 (0.097)	-0.231** (0.107)	
Industry growth	0.965*** (0.024)			0.966*** (0.024)		
Profitability$_{t-1}$		0.459*** (0.019)			0.458*** (0.019)	
Risk$_{t-1}$			0.754*** (0.010)			0.737*** (0.011)
Organizational form (mutual=1, stock=0)	-0.022*** (0.004)	-0.020*** (0.003)	-0.005*** (0.002)	-0.022*** (0.004)	-0.020*** (0.003)	-0.005*** (0.001)
Line of business (life=1, non-life=0)	0.022*** (0.005)	-0.023*** (0.004)	0.0001 (0.001)	0.023*** (0.005)	-0.022*** (0.004)	-0.0003 (0.001)
Ln(Firm size)$_{t-1}$	-0.010*** (0.001)	0.006*** (0.001)	0.0002 (0.0003)	-0.010*** (0.001)	0.006*** (0.001)	0.0003 (0.0003)
GDP growth	0.007 (0.071)	-0.292*** (0.077)	-0.189*** (0.028)	0.013 (0.071)	-0.243*** (0.076)	-0.206*** (0.028)
Long-term interest rate	-0.244** (0.123)	-0.164 (0.116)	0.189*** (0.048)	-0.256** (0.124)	-0.099 (0.119)	0.130*** (0.048)
Inflation	-0.072 (0.184)	-0.460*** (0.162)	0.194*** (0.058)	-0.085 (0.185)	-0.398** (0.167)	0.163*** (0.057)
Concentration ratio	0.009 (0.012)	-0.014 (0.012)	0.009** (0.004)	0.007 (0.012)	-0.015 (0.012)	0.009** (0.004)
Penetration ratio	0.005 (0.096)	-0.159* (0.084)	0.123*** (0.030)	0.001 (0.096)	-0.148* (0.084)	0.112*** (0.030)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.319	0.274	0.670	0.319	0.276	0.673
F Statistic	253***	162***	593***	217***	139***	549***
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix O

Alternative profitability measure (ROA before taxes)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.043^{***} (0.004)	-0.053^{***} (0.008)		0.055^{***} (0.005)	-0.073^{***} (0.012)
Growth^2					-0.022^{***} (0.006)	0.044^{***} (0.016)
Profitability	0.031 (0.113)		-0.164^{***} (0.029)	0.215 (0.272)		-0.398^{***} (0.062)
Profitability^2				-1.432 (1.645)		1.820^{***} (0.373)
Risk	-0.021 (0.032)	0.023^{***} (0.004)		0.089 (0.079)	0.054^{***} (0.011)	
Risk^2				-0.201 (0.139)	-0.058^{***} (0.019)	
Industry growth	0.994^{***} (0.065)			0.991^{***} (0.065)		
Profitability$_{t-1}$		0.525^{***} (0.018)			0.524^{***} (0.018)	
Risk$_{t-1}$			0.773^{***} (0.011)			0.769^{***} (0.011)
Organizational form (mutual=1, stock=0)	-0.030^{***} (0.005)	-0.003^{***} (0.001)	-0.005^{***} (0.002)	-0.029^{***} (0.005)	-0.003^{***} (0.001)	-0.006^{***} (0.002)
Line of business (life=1, non-life=0)	0.014^{*} (0.008)	-0.013^{***} (0.001)	-0.003^{*} (0.002)	0.016^{*} (0.008)	-0.012^{***} (0.001)	-0.006^{***} (0.002)
Ln(Firm size)$_{t-1}$	-0.006^{***} (0.001)	-0.001^{***} (0.0002)	0.0001 (0.0003)	-0.006^{***} (0.001)	-0.001^{***} (0.0002)	0.0001 (0.0003)
GDP growth	-0.006 (0.131)	-0.032^{*} (0.018)	-0.233^{***} (0.031)	0.003 (0.132)	-0.039^{**} (0.018)	-0.211^{***} (0.031)
Long-term interest rate	-0.199 (0.188)	-0.047^{*} (0.028)	0.255^{***} (0.053)	-0.219 (0.188)	-0.039 (0.029)	0.217^{***} (0.052)
Inflation	-0.015 (0.292)	-0.178^{***} (0.040)	0.265^{***} (0.060)	-0.027 (0.292)	-0.163^{***} (0.040)	0.214^{***} (0.061)
Concentration ratio	0.009 (0.017)	0.0004 (0.003)	0.009^{**} (0.004)	0.006 (0.018)	0.00005 (0.003)	0.008^{*} (0.004)
Penetration ratio	0.0003 (0.148)	0.009 (0.021)	0.130^{***} (0.034)	-0.007 (0.148)	0.007 (0.021)	0.130^{***} (0.034)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.159	0.372	0.663	0.159	0.374	0.665
F Statistic	50^{***}	281^{***}	563^{***}	42^{***}	237^{***}	514^{***}
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix P

Alternative risk measure (5-year window for moving standard deviation of ROE before tax)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.155^{***} (0.021)	-0.022^{***} (0.008)		0.179^{***} (0.023)	-0.031^{***} (0.010)
Growth^2					-0.042^{**} (0.018)	0.016^{**} (0.006)
Profitability	0.039 (0.039)		-0.085^{***} (0.008)	0.019 (0.068)		-0.170^{***} (0.017)
Profitability^2				0.051 (0.168)		0.237^{***} (0.049)
Risk	-0.012 (0.032)	0.217^{***} (0.029)		0.044 (0.083)	0.207^{***} (0.071)	
Risk^2				-0.122 (0.159)	0.018 (0.164)	
Industry growth	0.992^{***} (0.078)			0.992^{***} (0.078)		
Profitability$_{t-1}$		0.453^{***} (0.021)			0.452^{***} (0.021)	
Risk$_{t-1}$			0.835^{***} (0.009)			0.820^{***} (0.010)
Organizational form (mutual=1, stock=0)	-0.027^{***} (0.006)	-0.025^{***} (0.004)	-0.007^{***} (0.002)	-0.027^{***} (0.006)	-0.025^{***} (0.004)	-0.007^{***} (0.001)
Line of business (life=1, non-life=0)	0.012 (0.007)	-0.009^{**} (0.004)	-0.002^{*} (0.001)	0.012^{*} (0.007)	-0.008^{*} (0.004)	-0.003^{*} (0.001)
Ln(Firm size)$_{t-1}$	-0.005^{***} (0.001)	0.003^{***} (0.001)	0.001^{**} (0.0003)	-0.005^{***} (0.001)	0.004^{***} (0.001)	0.001^{***} (0.0003)
GDP growth	-0.002 (0.117)	-0.270^{***} (0.081)	-0.229^{***} (0.027)	0.001 (0.117)	-0.283^{***} (0.080)	-0.217^{***} (0.027)
Long-term interest rate	-0.172 (0.204)	-0.501^{***} (0.135)	0.019 (0.046)	-0.191 (0.204)	-0.465^{***} (0.137)	-0.014 (0.045)
Inflation	0.019 (0.302)	-0.804^{***} (0.184)	0.288^{***} (0.063)	0.008 (0.303)	-0.767^{***} (0.183)	0.268^{***} (0.062)
Concentration ratio	0.007 (0.017)	-0.001 (0.014)	0.007^{*} (0.004)	0.006 (0.017)	-0.0003 (0.014)	0.007^{*} (0.004)
Penetration ratio	0.001 (0.147)	-0.288^{***} (0.098)	0.088^{***} (0.029)	-0.004 (0.147)	-0.287^{***} (0.098)	0.082^{***} (0.029)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.159	0.241	0.748	0.159	0.241	0.750
F Statistic	35^{***}	92^{***}	858^{***}	31^{***}	79^{***}	802^{***}
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix Q

Alternative risk measure (6-year window for moving standard deviation of firm ROE before tax)

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.126^{***} (0.030)	-0.003 (0.007)		0.146^{***} (0.034)	-0.013 (0.010)
Growth^2					-0.025 (0.018)	0.011^{*} (0.006)
Profitability	0.044 (0.045)		-0.061^{***} (0.008)	0.048 (0.063)		-0.137^{***} (0.013)
Profitability^2				-0.013 (0.185)		0.234^{***} (0.041)
Risk	-0.009 (0.035)	0.152^{***} (0.027)		0.005 (0.086)	0.279^{***} (0.059)	
Risk^2				-0.026 (0.170)	-0.255^{**} (0.115)	
Industry growth	0.994^{***} (0.124)			0.994^{***} (0.124)		
Profitability$_{t-1}$		0.439^{***} (0.023)			0.438^{***} (0.023)	
Risk$_{t-1}$			0.885^{***} (0.012)			0.872^{***} (0.013)
Organizational form (mutual=1, stock=0)	-0.018^{***} (0.007)	-0.022^{***} (0.004)	-0.003^{*} (0.002)	-0.018^{***} (0.007)	-0.021^{***} (0.004)	-0.003^{**} (0.002)
Line of business (life=1, non-life=0)	0.007 (0.008)	-0.004 (0.005)	-0.003^{*} (0.001)	0.007 (0.008)	-0.002 (0.005)	-0.003^{*} (0.001)
Ln(Firm size)$_{t-1}$	-0.003^{**} (0.001)	0.002^{**} (0.001)	0.001^{**} (0.0003)	-0.003^{**} (0.001)	0.002^{**} (0.001)	0.001^{**} (0.0003)
GDP growth	0.003 (0.156)	-0.509^{***} (0.102)	-0.068^{**} (0.030)	0.005 (0.157)	-0.488^{***} (0.102)	-0.069^{**} (0.030)
Long-term interest rate	-0.078 (0.344)	-0.925^{***} (0.169)	-0.047 (0.059)	-0.078 (0.340)	-0.903^{***} (0.175)	-0.090 (0.059)
Inflation	0.040 (0.326)	-0.846^{***} (0.199)	0.151^{**} (0.062)	0.037 (0.326)	-0.853^{***} (0.200)	0.141^{**} (0.062)
Concentration ratio	0.005 (0.019)	-0.011 (0.015)	0.018^{***} (0.004)	0.004 (0.020)	-0.013 (0.015)	0.018^{***} (0.004)
Penetration ratio	0.006 (0.180)	-0.322^{***} (0.121)	0.106^{***} (0.037)	0.005 (0.181)	-0.328^{***} (0.121)	0.098^{***} (0.036)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.143	0.229	0.822	0.142	0.230	0.823
F Statistic	25^{***}	68^{***}	604^{***}	21^{***}	59^{***}	651^{***}
Country dummies	No	No	No	No	No	No
Year dummies	No	No	No	No	No	No

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. A constant term is included, but not reported.

Appendix R

OLS estimation with year dummies per country

	Model (1)			Model (2)		
	Growth	Profitability	Risk	Growth	Profitability	Risk
Growth		0.038^{***} (0.006)	-0.002 (0.002)		0.072^{***} (0.008)	-0.009^{***} (0.003)
$Growth^2$					-0.032^{***} (0.006)	0.005^{**} (0.002)
Profitability	0.050^{***} (0.015)		-0.069^{***} (0.004)	0.030^{*} (0.017)		-0.143^{***} (0.004)
$Profitability^2$				0.084^{**} (0.040)		0.344^{***} (0.008)
Risk	-0.014 (0.025)	-0.040^{***} (0.015)		0.014 (0.058)	0.059^{*} (0.035)	
$Risk^2$				-0.108 (0.107)	-0.203^{***} (0.066)	
Industry growth	0.984^{***} (0.032)			0.984^{***} (0.032)		
$Profitability_{t-1}$		0.503^{***} (0.009)			0.499^{***} (0.009)	
$Risk_{t-1}$			0.758^{***} (0.006)			0.709^{***} (0.005)
Organizational form (mutual=1, stock=0)	-0.029^{***} (0.006)	-0.025^{***} (0.004)	-0.005^{***} (0.001)	-0.028^{***} (0.006)	-0.026^{***} (0.004)	-0.001 (0.001)
Line of business (life=1, non-life=0)	0.017^{***} (0.006)	-0.011^{***} (0.004)	-0.001 (0.002)	0.018^{***} (0.006)	-0.009^{**} (0.004)	-0.001 (0.001)
$Ln(Firm\ size)_{t-1}$	-0.007^{***} (0.001)	0.004^{***} (0.001)	0.001^{***} (0.0003)	-0.007^{***} (0.001)	0.004^{***} (0.001)	0.001^{***} (0.0003)
GDP growth	-0.036 (0.143)	0.434^{***} (0.086)	-0.204^{***} (0.034)	-0.030 (0.143)	0.414^{***} (0.086)	-0.186^{***} (0.031)
Long-term interest rate	-0.087 (0.271)	-0.662^{***} (0.166)	0.197^{***} (0.066)	-0.095 (0.271)	-0.643^{***} (0.166)	0.160^{***} (0.060)
Inflation	-0.045 (0.305)	-0.738^{***} (0.185)	0.165^{**} (0.073)	-0.057 (0.305)	-0.666^{***} (0.185)	0.129^{*} (0.067)
Concentration ratio	-0.016 (0.031)	0.080^{***} (0.019)	-0.027^{***} (0.007)	-0.017 (0.031)	0.077^{***} (0.019)	-0.020^{***} (0.007)
Penetration ratio	0.011 (0.150)	-0.124 (0.092)	0.042 (0.036)	0.009 (0.150)	-0.109 (0.092)	0.024 (0.033)
Observations	9,298	9,298	9,298	9,298	9,298	9,298
Number of firms	1,988	1,988	1,988	1,988	1,988	1,988
Adjusted R^2	0.152	0.326	0.701	0.152	0.329	0.748
F Statistic	17^{***}	45^{***}	214^{***}	17^{***}	45^{***}	266^{***}

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are standard errors. A constant term and time dummies per country are included, but not reported.

Appendix S

Risk and profitability over time

Final performance group	Low risk, high profitability			High risk, low profitability		
Initial performance group	High risk, low profitability	z-test	High profitability, high risk	High risk, low profitability	z-test	High profitability, high risk
2006–2013	1.45	**	8.76	9.18		7.66
2006–2012	26.49	**	17.06	26.49	***	7.65
2006–2011	9.18	***	20.44	13.04		10.58
2006–2010	4.85	***	17.65	32.84	***	3.53
2006–2009	14.01		14.96	4.35	***	16.06
2006–2008	2.24	***	10.59	31.34	***	0.00
2006–2007	0.48	**	11.31	44.93	***	14.6

Notes: The table shows percentages of insurers that move from the initial performance group to the final performance group in the specified period (see Davidsson et al., 2009). $***$, $**$, and $*$ represent significance at the 1%, 5%, and 10% levels, respectively.

Part III

The Impact of Capacity on Price and Productivity Change in Insurance Markets: New Firm-Level Evidence

MARTIN ELING, ROBERT E. HOYT, and PHILIPP SCHAPER

Abstract

We find evidence for the capacity-constraint hypothesis in a newly constructed sample of firm-level data for the German non-life insurance market over an extended period (1954–2016). Moreover, we show that the impact of capacity on price is complex and depends on various exogenous factors (interest rate change, catastrophes, GDP growth, and regulation). We also find that decreased firm capacity has a negative impact on productivity change. The dual impact of capacity is important since price and productivity change determine firm profitability. Our results yield important implications for the understanding of underwriting cycles and re-emphasize the role of capacity in the business of insurance.

Keywords: Capacity-constraint hypothesis · Underwriting cycle · Productivity

JEL classification: D24 · E39 · G22 · L11

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1 Introduction

Extant literature shows that prices and productivity fluctuate over time. Cyclical price patterns in the insurance industry are termed *underwriting cycles*. The capacity-constraint hypothesis of Gron (1994) and Winter (1994) states that the price fluctuations are caused by shocks to capital that constrain capacity (see Meier & Outreville, 2006, for an overview of the analyzed drivers). Economic theory suggests that capacity determines not only prices but also productivity (Schultze, 1963). Furthermore, previous literature mentions that capacity depends on various exogenous factors (Doherty & Garven, 1995; Weiss, 2007; Berry-Stölzle & Born, 2010; Bruneau & Sghaier, 2015). Browne and Hoyt (1995) document the importance of exogenous market and economic factors in the context of insurer financial distress, which is also closely related to capital. Browne and Hoyt (1992) find a cycle in excess returns in the property-liability insurance sector, which is closely correlated with the underwriting cycle. Understanding the role of capacity is thus central, especially given that the interplay of price and productivity determines firm profitability and thus financial strength (Grifell-Tatjé & Lovell, 2015).

To date, there is no definitive conclusion on the causes of underwriting cycles. While the capacity-constraint hypothesis has gained much empirical support using industry data, the evidence from firm-level data is both limited and ambiguous. Cummins and Danzon (1997) cannot support the capacity-constraint hypothesis using firm-level data of U.S. general liability insurers in 1976–1987; the results show the opposite impact than expected. In contrast, Weiss and Chung (2004) find evidence for the capacity-constraint hypothesis in a sample of large U.S. property-casualty reinsurers in 1991–1995. Besides the lack of firm-level analyses over long periods in the literature on underwriting cycles, there is a need to analyze the determinants of the capacity-price relationship. In addition, there is still a limited understanding of the drivers of productivity change in the insurance sector and to our knowledge, the role of capacity has not yet been analyzed.[1]

The purpose of this article is to analyze the impact of capacity on prices and productivity change using firm-level data so that we can then explore the role of exogenous factors. We use a new sample of hand-collected data on 251 insurance companies from the German non-life market (excluding health) for 1954–2016 (6,027 firm-year observations). Our sample encompasses numerous interest rate changes, years with high catastrophic losses, periods of business contraction and expansion, and two regulatory regimes (pre- and post-deregulation in 1994); all of these factors are identified in the literature as relevant moderators of the capacity impact. Thus, our sample allows us to

[1] Cummins and Xie (2013) provide some first side-results for the capacity-productivity relationship. The authors find the premiums-to-capital ratio as significant driver of productivity change. However, the authors do not disentangle firm and industry capacity and do not separately control for financial quality/leverage (see Section 2). Thus, the results in Cummins and Xie (2013) may also reflect implications of the risky-debt hypothesis.

explore the role of capacity for price and productivity in greater depth. Our approach also allows us to analyze determinants of both price and productivity change in a common sample. In addition, this study is the first firm-level analysis of productivity over such a long period in the insurance sector.

In line with Weiss and Chung (2004), we find support for the capacity-constraint hypothesis and show that both firm and industry capacity are relevant price determinants. Our results suggest that if firm and/or industry capacity is reduced, insurers tend to increase prices in the next period, probably to replenish their capital (Gron, 1994; Winter, 1994). We also find that the capacity-price relationship is moderated by exogenous factors. Specifically, prices are more sensitive to decreased capacity following interest rate declines, years with catastrophic losses, and negative GDP shocks. With regards to regulation, our results suggest that the impact of capacity on price was greater pre-deregulation. In addition, we find support for the risky-debt hypothesis of Cummins and Danzon (1997) suggesting that safer insurers can charge higher prices. Firm capacity is also a significant driver of productivity change; however, industry capacity seems to play no role in productivity development.

This study demonstrates that exogenous factors may not only by themselves influence the underwriting cycle—as demonstrated by previous literature (see Cummins & Outreville, 2006, for an overview)—but also moderate the impact of capacity. This result highlights that the role of capacity is complex, a finding that is also relevant for the discussion on whether cycles can be forecast. As reflected in annual assessments produced each year by many business consultants, underwriting cycles in insurance remain a critical factor in forecasting insurance firm performance and to predicting the likely effects on insurance consumers (see, e.g., Marsh, 2017; Swiss Re, 2017; Deloitte, 2018). The importance of capital and the impact of exogenous factors such as those included in our study are also reflected in such business analysis.[2] This reinforces the contribution of our study not only to the academic literature on insurance cycles, but also to relevant and timely discussions in the business of insurance.

The remainder of the paper is organized as follows. In Section 2, we discuss the background and derive our hypotheses. Section 3 presents the variables and data used for later regression analyses. Section 4 presents our methodology. Section 5 discusses the empirical results and Section 6 concludes.

[2] Marsh (2017) and Deloitte (2018) state that the current soft insurance cycle appears to be “mainly due to an overabundance of capital.” Reflecting the importance of exogenous factors, Deloitte (2018) also notes that insurers face “a wide range of challenges. Not all of them are within the industry’s control, such as rising interest rates and catastrophe losses.” Deloitte (2018) adds that “regulation and compliance requirements are important and seem ever-changing.” Finally, reflecting the recognition that both capital and productivity are important, Deloitte (2018) concludes that “insurers can take advantage of growth opportunities, operational improvement, and expense reduction in 2018 if they can overcome a host of internal and external obstacles standing in their way.”

2 Background and hypotheses development

Economic theory posits that capacity is related to capital and that it is a mutual determinant of price and productivity (Schultze, 1963; Grifell-Tatjé & Lovell, 2015). A common capacity measure in insurance is the premiums-to-capital ratio (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015) and price is commonly proxied by the loss or combined ratio because premiums per exposure are usually not publicly available (Harrington, Niehaus, & Yu, 2013). In line with the literature, we use Malmquist indices to measure productivity change (Cummins & Weiss, 2013). To our knowledge, other methodologies to measure productivity have not been applied since they require price information in order to weigh inputs and outputs in a multidimensional framework (Grifell-Tatjé & Lovell, 2015). This information is usually not publicly available at the firm level.

An important consideration in the discussion of capacity in the insurance sector is the assumption that capital does not freely flow into the industry because firms tend to face transaction costs for raising capital (Cummins & Danzon, 1991).[3] Furthermore, empirical evidence initially suggests that the impact of capacity in the insurance sector changes over time and depends on a variety of exogenous factors. Berry-Stölzle and Born (2010) provide evidence that the regulatory environment affects the role of capacity constraints. In their analysis, lagged capital changes have a significant negative impact on premium change post- but not pre-deregulation. In contrast, Bruneau and Sghaier (2015) find that capacity constraints were not binding in 1995–2010 in the French property-liability insurance sector, a period that encompassed various regulatory changes in the European Union (EU). Further, literature suggests that the interest rate development (Doherty & Garven, 1995), catastrophic losses (see Weiss, 2007, for a review), and the general business cycle (Berry-Stölzle & Born, 2010) interact with capacity. Specifically, if adverse exogenous "shocks" increase the need to replenish capital, a stronger price/productivity reaction is expected.[4]

In the following, we review prior literature, describe the relationship between capacity and price/productivity change, and discuss the moderating role of exogenous factors that are derived from previous literature. We focus on moderation (i.e., interaction) and do not consider mediation because, based on prior literature, we expect the relationship between capacity and price/productivity to vary depending on the severity of the exogenous factors (see, e.g., Doherty & Garven, 1995). By contrast, meditation would

[3] The main consideration here is that costs of financing generally increase with asymmetric information, thus making external capital more costly than internal capital (Myers & Majluf, 1984). Therefore, firms tend to prioritize internal capital, then debt, and finally equity.

[4] One may also argue that firm-specific shocks to capital (e.g., firm-specific loss shocks) encourage the insurer to raise prices in order to increase its capital base (Cummins & Danzon, 1997). However, whether the insurer can increase prices also depends on whether its financial quality is impaired; if it is, the insurer is unlikely to achieve higher prices if competitors' financial quality is unchanged and customers can freely change companies.

assume that the exogenous factors intervene in or interrupt the relationship between capacity and price/productivity change. Table 1 summarizes the hypotheses that we develop and test in later regression analyses.

Table 1 Overview of hypotheses

The impact of capacity on price
H1a: Firm capacity is negatively related to price.
H1b: Industry capacity is negatively related to price.
H1c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-price relationship.
The impact of capacity on productivity change
H2a: Firm capacity drives productivity change but the direction of impact is ambiguous.
H2b: Industry capacity drives productivity change but the direction of impact is ambiguous.
H2c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-productivity change relationship.

The impact of capacity on price

If capacity is reduced and transactions costs for raising new external capital exist, insurers may raise prices to replenish capital internally (see Weiss, 2007, for a review of the underwriting cycle literature). Insurers facing higher transaction costs (e.g., agency costs) may show stronger price responses (Cummins & Danzon, 1991).[5]

To date, two theories have formalized the relationship between capital and price in the insurance sector. The capacity-constraint hypothesis (Gron, 1994; Winter, 1994) posits that prices are inversely related to industry capacity. If capacity (industry capital) is reduced (e.g., through an industry-wide shock) insurers replenish capital via increased prices. The risky-debt hypothesis (Cummins & Danzon, 1997) posits that insurer-specific prices depend on financial quality of the insurer. Customers are willing to pay higher prices for coverage from safer insurers and, similar to risky debt, prices fall as default risk increases (Lei & Browne, 2017). Generally, the capacity-constraint and risky-debt hypotheses are consistent because the former hypothesis focuses on industry capital and the later on insurer-specific capital (Weiss & Chung, 2004; Weiss, 2007). Specifically, both hypotheses agree that overall capital supply affects pricing, but effects vary by firm such that better capitalized insurers benefit from their position by charging higher prices.

5 Cummins and Danzon (1991) as well as Doherty and Garven (1995) show that observed prices deviate more from financial pricing models if the interest rate changes for insurers with higher transaction costs to raise new capital (i.e., private and/or smaller insurers and insurers with less access to reinsurance).

At the industry level, Gron (1994) finds that deviations in relative capacity (capital to Gross National Product, GNP) have an inverse relationship with underwriting profits in line with the capacity-constraint hypothesis (i.e., price increases if capacity is reduced). Winter (1994) provides evidence that reduced capital is associated with lower loss ratios, again in line with the capacity-constraint theory.

At the firm level, Cummins and Danzon (1997) disentangle firm from industry capacity and measure financial quality for a sample of 50 U.S. general liability insurers in 1976–1987. Cummins and Danzon (1997) find that price is positively related to financial quality (ratio of capital to liabilities) meaning that better-capitalized insurers can charge higher prices supporting their risky-debt hypothesis. However, Cummins and Danzon (1997) find contradictory results for the capacity-constraint hypothesis—the firm and industry capacity variables are positively related to price. Weiss and Chung (2004) analyze a sample of large U.S. property-casualty reinsurers in 1991–1995 and find evidence for both the capacity-constraint and risky-debt theory.

A distinction must therefore be made between firm and industry capacity while considering firm-specific financial quality as separate price determinant. Both firm and industry capacity should have the same coefficient sign (Cummins & Danzon, 1997): a decrease (increase) in capacity suggests a positive (negative) impact on price. Thus, we formulate our first two hypotheses.

Hypothesis 1a: *Firm capacity is negatively related to price.*
Hypothesis 1b: *Industry capacity is negatively related to price.*

The moderation of exogenous factors ("shocks") in the capacity-price relationship

a) Interest rate change

Wilson (1981), Doherty and Kang (1988), Fields and Venezian (1989), and Fung et al. (1998) emphasize the role of changes in interest rates for the underwriting cycle. The main consideration is that the equilibrium price changes in lagged response to changing interest rates (Doherty & Garven, 1995). Doherty and Garven (1995) combine the interest rate and capacity constraint models and show that interest rate changes affect prices both directly and indirectly through capital changes given the gaps in asset-liability duration. If the asset duration exceeds the duration of liabilities, negative interest rate changes, *ceteris paribus*, reduce capital. Consequently, insurers may raise their prices to replenish capital if raising external capital is more expensive (Weiss, 2007). Thus, interest rate changes may moderate the capacity-price relationship. If interest rates fall, capacity constraints may become more binding, increasing the incentive to raise prices for insurers. This implies a positive moderation of interest rate changes.

b) Catastrophic losses

As explained by capital shock theories, insurer capital is not only sensitive to interest rate movements but also to adverse loss shocks (Weiss, 2007). In line with the capacity-constraint hypothesis (Gron, 1994; Winter, 1994), insurers increase prices to replenish capital due to constrained capacity following loss shocks that reduce capital (Weiss, 2007)—thus, showing a similar response as explained for adverse interest rate movements. In this way, catastrophic losses may negatively moderate the capacity-price relationship.

c) The general business cycle (GDP growth)

Prior literature also emphasizes the importance of the general business cycle for the underwriting cycle (Grace & Hotchkiss, 1995; Lamm-Tennant & Weiss, 1997; Chen, Wong, & Lee, 1999). The general business cycle also influences capacity in various industries (Schultze, 1963; Kendrick & Grossman, 1980) and possible also in the insurance sector (Berry-Stölzle & Born, 2010). During (at the beginning of) upswings with increasing demand for insurance, capacity constraints may become more binding. If demand expectations are sustainable, insurers may raise prices to increase the capital basis. Excess capacity (Berry-Stölzle & Born, 2012) during downturns may be used to cut prices. This implies a positive moderation of GDP growth.

d) The regulatory environment

Bruneau and Sghaier (2015) demonstrate that different capacity regimes existed in the French property-liability industry in 1963–2010. Interestingly, the capacity constraint is binding if the premiums-to-capital ratio is less than 2.22.[6] This threshold was not undercut in France in 1995–2010 (Bruneau & Sghaier, 2015); the premiums-to-capital ratio has sharply decreased since 1995. This result suggests that capacity constraints have not played a role since then. The result is of particular interest since the period from 1995 onwards brought two major regime changes in the EU. In 1994, the third generation of non-life Insurance Directives designed to open and harmonize the European insurance markets was introduced (Rees & Kessner, 1999). The year 2007 saw the launch of the formal legislative process for an EU directive that codifies and harmonizes EU insurance capital adequacy (Solvency II).

While France had traditionally been subject to low insurance regulation, the German insurance industry was heavily regulated until 1994, when the EU Directives forced EU-wide deregulation and thus significantly influenced the German insurance market (Rees & Kessner, 1999; Flockton, Grout, & Yong, 2004). Berry-Stölzle and Born (2012) find that policy form regulation until 1994 did not increase aggregated prices (loss ratio) in

6 In fact, Bruneau and Sghaier (2015) use the inverse premiums-to-capital ratio which relates to a threshold of 0.45.

the German property-liability insurance industry above competitive levels; however, in highly competitive (remaining) lines prices decreased (increased) post-deregulation. Berry-Stölzle and Born (2010) demonstrate that the 1994 deregulation changed the importance of internal and external factors for the premium-setting process in the German property-casualty sector. Although, Berry-Stölzle and Born (2010) do not find general support for the capacity-constraint hypothesis in their industry-level premium change model, it does find some evidence that lagged capital changes have a significant negative impact on premium change post-deregulation but not pre-deregulation. In addition, the evidence in Bruneau and Sghaier (2015) may emphasize that the impact of capacity is moderated by regulatory regimes. Thus, the impact of capacity on price may vary over time (e.g., due to different regulatory regimes).

Overall, based on our discussions we formulate our next hypothesis.

Hypothesis 1c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-price relationship.

The impact of capacity on productivity change

Capital is a central input factor of insurers (Cummins & Weiss, 2013). The relationship between capacity and productivity in the insurance sector has, to our knowledge, not yet been analyzed. Grifell-Tatjé and Lovell (2015) provide a general framework to decompose productivity change, which identifies change in capacity utilization as a central determinant. Consistent with Schultze (1963), the authors do not prejudge the direction of impact. Schultze (1963) emphasizes that the relationship between capacity and productivity in general is complex and, depends on such things as the stage of the business cycle.[7]

For the insurance sector, an increase in the premium-to-capital ratio may indicate that capacity is used more efficiently, suggesting high productivity in the current period (Kendrick & Grossman, 1980). If insurer capital is reduced due to a shock, *ceteris paribus*, this also leads to higher productivity in the current period. These arguments suggest a positive relationship between the premiums-to-capital ratio and current productivity in the insurance sector. However, the implications of an increase in the ratio for productivity change is not evident.

An increase in the premiums-to-capital ratio may indicate that capacity constraints become more binding (Higgins & Thistle, 2000). Without increasing the capital basis, the scope to increase output in the next period is limited. Thus, high premiums-to-capital

[7] During downturns, there is incentive to retain important input factors such as skilled employees because it is expensive to hire and train new employees. During upswings, if output reaches capacity, productivity grows more slowly as increasing the input base may have time lags because it depends on a long-term expectation. If capacity, especially in upswings, cannot be freely increased as is assumed in the insurance industry, the impact on productivity is ambiguous.

ratios may delay or even hinder productivity growth. The capacity-constraint hypothesis suggests that the industry reduces supply after industry-wide capital shocks, while the demand for insurance remains constant. Thus, output quantity may decline but it is ambiguous to which extent in relation to the decreased capital input. In addition, it is ambiguous whether insurers adjust other input factors. Therefore, the net impact of the premiums-to-capital ratio on productivity change is not trivial. Cummins and Xie (2013) find that the premiums-to-capital ratio has an inverse relationship with productivity change in a firm-level analysis of the U.S. property-casualty industry from 1993–2009. This could be evidence that a decrease in capacity (increase in the premiums-to-capital ratio) has a negative impact on productivity change.[8] However, we also cannot preclude that the relationship is non-linear; where increases in the premiums-to-capital ratio increase productivity change up to a certain threshold after which the positive impact either mitigates or even turns into a negative one. Following the discussion above, we disentangle capacity into its firm and industry dimensions.

The exogenous factors outlined in this section also appear to be relevant for the capacity-productivity relationship. Specifically, Schultze (1963) outlines that during upswings productivity growth may slow down as capacity is fully exploited and increasing capacity has time delays. Also, Kendrick and Grossman (1980) state that the economic activity influences capacity utilization, thereby affecting productivity. To our knowledge, only the direct impact of exogenous factors on productivity change has been analyzed so far in the literature. Huang and Eling (2012) demonstrate that GDP growth and the interest rate level directly influence the productivity development in the non-life insurance sector of the BRIC (Brazil, Russia, India, China) countries. Based on our discussions, we formulate hypotheses regarding the impact of capacity on productivity. Despite the empirical evidence of Cummins and Xie (2013), we only hypothesize that firm and industry capacity determine productivity change and do not prejudge the direction of impact in line with Grifell-Tatjé and Lovell (2015).

Hypothesis 2a: Firm capacity drives productivity change but the direction of impact is ambiguous.

Hypothesis 2b: Industry capacity drives productivity change but the direction of impact is ambiguous.

Hypothesis 2c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-productivity relationship.

[8] A higher premiums-to-capital ratio may also indicate a higher default risk of insurers (Cummins & Xie, 2013). Thus, this result could be also seen as consistent with the implications of the risky-debt hypothesis. In our analyses, we will disentangle the impacts of firm/industry capacity from financial quality/leverage.

3 Variables and data

3.1 Variables

Capacity

We define capacity as net premiums written relative to capital (i.e., the premiums-to-capital ratio) (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015). The advantage of this measure is that it gives an indication of whether capacity constraints are binding. Furthermore, it is consistent with the idea of capacity utilization (Schultze, 1963; Grifell-Tatjé & Lovell, 2015); a high (low) level may indicate that capacity is (not) extensively utilized meaning that the insurer has less (more) scope to accept new business.

In order to distinguish firm and industry capacity we follow the approach of Cummins and Danzon (1997) and decompose the premiums-to-capital ratio into two orthogonal components.[9] In detail, we run a pooled regression model with the firm-specific premiums-to-capital ratio as dependent variable and the corresponding annual industry value as regressor. Industry capacity is the predicted value from this regression and firm capacity is the residual. Thus, industry capacity varies over time but not cross-sectionally. The orthogonalization also removes a source of collinearity between the firm and industry capacity variables.

Price

We proxy price by the ratio of losses and operating expenses to earned premiums (i.e., the combined ratio) (Bruneau & Sghaier, 2015). Thus, the coefficient signs of predictors in later regression analyses must be interpreted as follows. A positive (negative) coefficient suggests a negative (positive) impact of that predictor on price. We do not use the inverse of the combined ratio because this transformation causes the variable to be highly skewed.

Inputs for Malmquist productivity analysis

We follow the literature (see Eling & Luhnen, 2010, for an overview) and use labor (x_1), debt capital (x_2) and equity capital (x_3) as input variables. The business and materials input of insurers (Cummins & Weiss, 2013) cannot be modelled separately due to data limitations and is therefore integrated into the labor input (Biener, Eling, & Wirfs, 2016). The labor input is estimated by dividing net operating expenses by average annual wage rates.

[9] Cummins and Danzon (1997) use firm-specific capital levels from the previous year in relation to the average level of the preceding five years. Besides the advantages of the premiums-to-capital ratio, a use of the alternative measure would shorten the sample period by six years.

Outputs for Malmquist productivity analysis

We follow the value-added approach to measure the risk-pooling/risk-bearing, intermediation, and financial services related to insured losses outputs of insurers (Cummins & Weiss, 2013). We proxy the first output (y_1) with the present value of losses paid adjusted for the change in the provision for outstanding claims (i.e., real incurred losses). To avoid negative numbers for this output (i.e., if the change in provisions is higher than the losses paid), this variable is shifted for the complete sample period (Biener et al., 2016). The intermediation output (y_2) is represented by the total investments value. The third service output is not modelled separately because it is highly correlated with the two other output variables (Eling & Luhnen, 2010).

Other firm characteristics and exogenous variables

In later regression analyses, we control for financial quality (capital/liabilities) to consider the risky-debt hypothesis (Cummins & Danzon, 1997; Weiss & Chung, 2004). We also account for firm size by the natural logarithm of total assets (Biener et al., 2016). We use two binary variables to control for the mutual and public organizational forms.

The insurance penetration ratio (total non-life premiums/GDP) is used to account for aggregated insurance demand (Harrington et al., 2013). The amount of competition is measured by the Herfindahl-Hirschman-Index (Elango, Ma, & Pope, 2008).[10] We account for the interest rate change by the annual differences between official discount rates. We account for years with catastrophic losses by a binary variable taking the value 1 if a year recorded an extraordinary increase in total market losses (increase of total market loss ratio by more than 4%) and 0 otherwise. The threshold was chosen based on a review of the loss ratio time series, which showed that years with increases in the loss ratio by more than 4% clearly stand-out from other years.[11] GDP growth rates proxy the general business cycle. We account for the pre- and post-deregulation periods with a binary variable that takes the value 1 until 1994 and 0 afterwards.[12]

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[10] Marsh (2017) notes that despite record-high catastrophic losses in 2017, prices did not increase in industrial property insurance due to the high level of competition.

[11] As a robustness test, we vary the threshold (5%, 6%, and 8%), leading to the same conclusions as presented later.

[12] The deregulation period post-1994 overlaps with efforts of increased solvency regulation in the German insurance sector (i.e., through the introduction of Solvency II) and thus the identification of effects may not be fully traceable to (de-)regulation. However, the variable still captures two different regulatory regimes in the German insurance sector.

3.2 Data

We hand collected data from annual publications of the *Hoppenstedt Versicherungsjahrbuch* for 1958–2010 (Luhnen, 2009; Mahlberg & Url, 2010; Braun, Schmeiser, & Rymaszewski, 2015) complemented by data from Bureau van Dijk's *orbis insurance focus* database. The final sample period is 1954–2016, which encompasses numerous interest rate changes, catastrophic years, contraction and expansion periods over the German business cycle, and two different regulatory regimes (pre- and post-deregulation in 1994). The sample comprises data from insurers that operate in the motor, casualty, liability, fire, transport, household, and homeowners insurance lines. The final sample includes 251 insurers and 6,027 firm-year observations. Over the entire period, the sample represents on average approximately 90% of total premiums written in the German non-life market (excluding health insurance).

The annual wage rates are computed based on monthly wage data for Industry and Services obtained from the German Federal Statistical Office. To our knowledge, no insurance-specific wage data is consistently and publicly available for the complete sample period. The total premium and loss data is obtained from the German Federal Financial Supervisory Authority. The GDP data also come from the German Federal Statistics Office. Discount rates are published by Deutsche Bundesbank. For comparative purposes, all firm-specific variables are inflated/deflated to 2010 using consumer price indexes based on inflation data from the Deutsche Bundesbank. All Saar Franc values in the database are converted to Deutsche Mark using the official exchange rate (0.008507) and all Deutsche Mark values are converted to Euro using the official exchange rate (0.511292). Saar Franc was the official currency of the Saarland until 1959 when it adopted the Deutsche Mark, two years after Saarland was incorporated into the Federal Republic of Germany. Deutsche Mark was the official currency of the Federal Republic of Germany until 2002, when the Euro was introduced. Table 2 presents summary statistics for the variables defined in chapter 3.1.

Table 2 Summary statistics

Variable	Definition	Mean	Median	SD
Capacity				
Firm capacity	Residual from pooled regression of firm-specific premiums-to-capital ratio on the industry ratio	-0.0000	-0.2087	1.9365
Industry capacity	Predicted value from pooled regression of firm-specific premiums-to-capital ratio on the industry ratio	3.2033	2.9795	0.8232
Price				
Combined ratio	(Operating expenses+losses)/earned premiums	0.9213	0.9390	0.1840
Inputs for Malmquist productivity analysis				
x1	Labor input	2,146.5	738.1	4,247.3
x2	Equity capital input (in Mio. Euros)	106.5	29.2	232.5
x3	Debt capital input (in Mio. Euros)	532.2	123.7	1,499.4
Outputs for Malmquist productivity analysis				
y1	Losses output (in Mio. Euro)	192.1	55.6551	404.1
y2	Investments output (in Mio. Euro)	552.7	124.4128	1,516.4
Other firm characteristics				
Financial quality	Capital/liabilities	0.3069	0.2321	0.2478
Size	Log(total assets)	5.2127	5.0441	1.5232
Mutual	Dummy variable: 1 if insurer is mutual, 0 otherwise	0.1716	0	0.3770
Public	Dummy variable: 1 if insurer is public, 0 otherwise	0.1424	0	0.3494
Exogenous variables				
Insurance penetration	Total non-life premiums/GDP	0.0231	0.0243	0.0036
Competition	Herfindahl-Hirschman-Index	0.0374	0.0372	0.0093
ΔInterest rate	Discount rate_t-Discount rate_{t-1}	-0.0006	-0.0004	0.0124
Catastrophic year	1 if year is classified as catastrophe year; 0 otherwise	0.1599	0	0.3666
GDP	Growth in GDP	0.0271	0.0230	0.0243
Regulation	1 until 1994; 0 afterwards	0.6536	1	0.4759

4 Methodology

Productivity change measurement

We follow standard insurance literature and estimate input-oriented Malmquist indexes of total factor productivity (TFP) to proxy productivity change (Cummins & Weiss, 2013). We follow Simar and Wilson (1999, 2000) and use bootstrapping to obtain robust results.

Stationarity testing

We test all variables used in the regression analyses for stationarity using Fisher-type augmented Dickey–Fuller and Phillips–Perron panel unit-root tests (Choi, 2001). In case the null hypothesis that all the panels contain a unit root cannot be rejected, we also test the variable in first difference.

Price and productivity change models

For the specification of the price equation, we orient at Lamm-Tennant and Weiss (1997) who analyze premium change and Cummins and Danzon (1997) as well as Weiss and Chung (2004). Equation (1) illustrates how the price determinants are analyzed.

$$\begin{aligned} Price_{it} = {} & \alpha_1 + \alpha_2 \Delta Loss_{1,i,t} + \alpha_3 \Delta Loss_{2,i,t} + \alpha_4 \Delta Loss_{3,i,t} + \alpha_5 Firm\ capacity_{i,t-1} \\ & + \alpha_6 Industry\ capacity_{i,t-1} + \alpha_7 Financial\ quality_{i,t-1} + \alpha_8 \Delta TFP_{i,t-1} + \alpha_9 Size_{i,t-1} + \alpha_{10} Size^2_{i,t-1} \\ & + \alpha_{11} Mutual_{i,t-1} + \alpha_{12} Public_{i,t-1} + \alpha_{13} Insurance\ penetration_{t-1} + \alpha_{14} Competition_{t-1} + \\ & + \alpha_{15} \Delta Interest\ rate_{t-1} + \alpha_{16} Catastrophic\ year_{t-1} + \alpha_{17} GDP_{t-1} + \alpha_{18} Regulation_{t-1} + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

where i denotes firm and t year. We consider firm- and year-fixed effects in Equation (1). The lagged loss variables ($\Delta Loss_{1,i,t} = \log(yl_{t-1}) - \log(yl_{t-2})$; $\Delta Loss_{2,i,t} = \log(yl_{t-2}) - \log(yl_{t-3})$; …) account for accounting and data collection lags in line with arbitrage theory (Cummins & Outreville, 1987; Lamm-Tennant & Weiss, 1997) as well as loss shocks (Cummins & Danzon, 1997). We include the financial quality variable (capital/liabilities) to control for the implications of the risky-debt hypothesis.

We orient at the regression model of Cummins and Xie (2013) to analyze the determinants of productivity change as shown in Equation (2).[13]

[13] See Mahlberg and Url (2010) for a productivity change regression model for insurance group data.

$$\begin{aligned}\Delta TFP_{i,t} &= \beta_1 + \beta_2 Firm\ capacity_{i,t-1} + \beta_3 Industry\ capacity_{i,t-1} + \beta_4 Financial\ quality_{i,t-1} \\ &+ \beta_5 Price_{i,t-1} + \beta_6 Size_{i,t-1} + \beta_7 Size^2_{i,t-1} + \beta_8 Mutual_{i,t-1} + \beta_9 Public_{i,t-1} \\ &+ \beta_{10} Insurance\ penetration_{t-1} + \beta_{11} Competition_{t-1} + \beta_{12} \Delta Interest\ rate_{t-1} \\ &+ \beta_{13} Catastrophic\ year_{t-1} + \beta_{14} GDP_{t-1} + \beta_{15} Regulation_{t-1} + \varepsilon_{it}.\end{aligned} \tag{2}$$

We also consider dynamic interactions among price and productivity change in Equations (1) and (2) and use standard errors which are robust to heteroskedasticity and serial correlation for estimating both equations.[14]

Hypothesis testing

The testing of our hypotheses proceeds as follows. First, we estimate Equations (1) and (2) as presented. A negative coefficient for the firm capacity variable in Equation (1) would suggest that a positive increase in the deviation of the firm-specific capacity variable (premiums-to-capital ratio) from the industry average has a positive impact on price (H1a). A negative coefficient of the industry capacity variable suggests that an increase in the premium-to-capital ratio in the whole industry has a positive impact on price (H1b).

A negative (positive) coefficient for the firm capacity variable in Equation (2) would suggest that a positive increase in the deviation of the firm-specific ratio from the industry average has a negative (positive) impact on productivity change (H2a) suggesting "productivity-related capacity constraints" (a more efficient usage of capacity leading to greater productivity change). A negative (positive) coefficient of the industry capacity variable suggests that an increase in the premium-to-capital ratio in the whole industry has a negative (positive) impact on productivity change (H2b). To test for non-linearity, we also introduce quadratic terms of the capacity variables into Equation (2).

Second, we gradually introduce interaction terms between the (lagged) firm capacity variable and a) the variable accounting for changes in the interest rate, b) the catastrophic year variable, c) GDP growth, and d) the regulation variable (1 until 1994, 0 afterwards) in Equations (1) and (2). This approach measures the interaction of capacity that enters the new period subject to the (lagged) exogenous factors. Significant interactions are evidence for moderation (H1c, H2c).

We focus on the interaction between the firm capacity variable and the exogenous factors as the corresponding interaction term varies cross-sectionally and over time,

[14] We also specified and tested impulse response functions in a linear panel VAR framework to analyze the dynamic interactions among capacity, price, and productivity change (Appendix A). However, the interactions are extremely difficult to model so the modelling is based on various discretionary decisions. In addition, the paradigmatic analysis in Appendix A provides preliminary evidence that the interactions, if any, are weakly dynamic and may thus be rather contemporaneous. To our knowledge, there are no valid instruments for all three variables available to analyze the contemporaneous interactions.

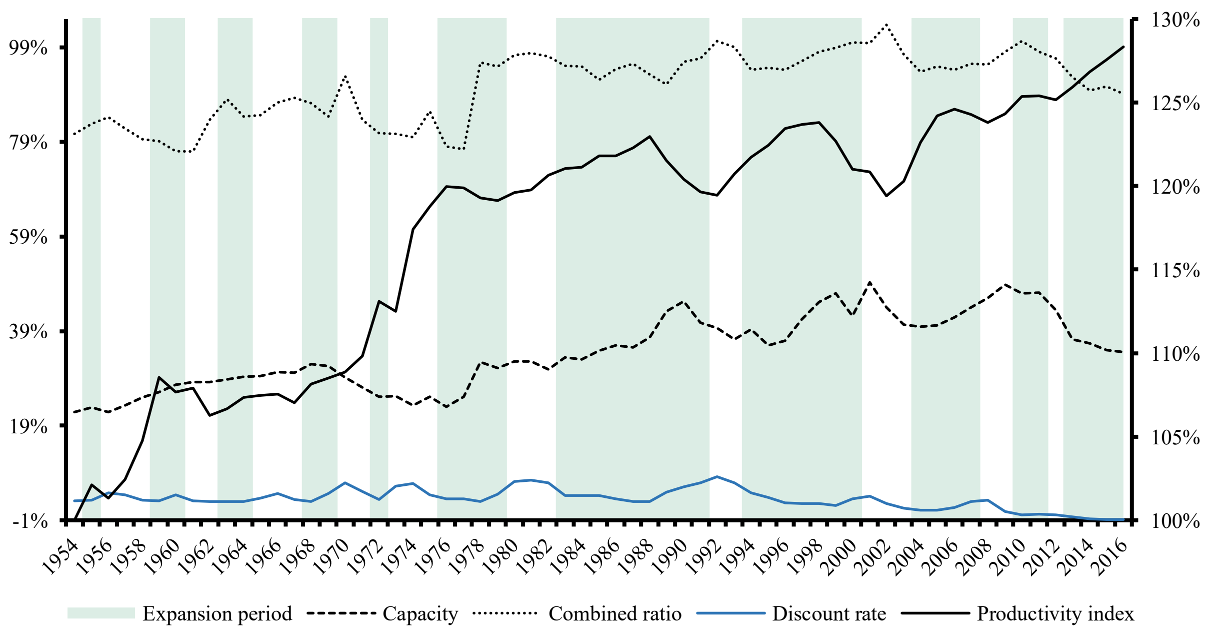
which leads to a good identification of moderating effects; in contrast, interaction terms between the industry capacity variable and the exogenous variables vary over time but not cross-sectionally. Nevertheless, the interaction terms between the firm capacity variable and the exogenous variables capture the impact of industry-wide “shocks”, as all firms are affected symmetrically (see, e.g., Winter, 1994) by, for example, interest rate changes. Thus, independent of the relative firm position in terms of capacity, all insurers experience the same impact of the exogenous factor on capacity while the relative capacity position is unaffected (see also Footnote 15).

In order to arrive at more meaningful interpretations of the interaction terms, we mean center all variables per panel that are used for constructing the terms. We also mean center variables before computing quadratic terms.

5 Empirical results

Figure 1 presents the development of capacity (premiums-to-capital ratio), price (combined ratio), and productivity in the German non-life market in 1954–2016. In addition, it illustrates the discount rate development and highlights expansion periods. For illustrative purposes, the inverse of the capacity measure is given.

Figure 1 Development of inverse capacity (premiums-to-capital ratio), price (combined ratio), and productivity (secondary axis)



Notes: Productivity index is created by multiplying median annual TFP change rates with the preceding year index value (1954=100%). For illustrative purposes, the inverse of the capacity measure (premiums-to-capital ratio) is shown. For all other variables median values are presented. Expansion periods are defined as shown in Appendix B.

The inverse capacity measure has significantly increased during the sample period (Figure 1). In 1954, the value is 0.22 growing to as high as 0.49 in 2001 and remaining as high as 0.35 in 2016, the last year of our sample period. This trend resembles Bruneau and Sghaier’s (2015) illustration of the capacity development in the French property-liability insurance sector, in which the inverse premiums-to-capital ratio increased from 0.18 in 1963 to 0.55 in 2010 at the aggregated level.

Figure 1 shows that the price proxy (combined ratio) moves in cycles during the sample period. Periods of increases in the combined ratio are usually followed by periods of sharp declines and vice versa. Prior literature has empirically verified the existence of the underwriting cycle in the German insurance market while documenting different cycle lengths depending on the analyzed period. Cummins and Outreville (1987) find an average cycle length of 7.76 years in 1957–1979, Lamm-Tennant and Weiss (1997) find an average cycle length of 6.45 years in 1965–1987, and Meier and Outreville (2006) find an average cycle length of 8.88 years in 1965–2001. Berry-Stölzle and Born (2010) demonstrate that by-line cycle periods differ in some lines pre- and post-deregulation. In Appendix D, we make a simple classification of hard and soft market periods based on the total loss ratio development that we use for an additional analysis of the price determinants in the two cycle phases later in this section.

Figure 1 illustrates that also productivity tends to be cyclical in the German non-life insurance sector, which is in line with findings for other industries (Kendrick & Grossman, 1980; Grifell-Tatjé & Lovell, 2015). The median productivity development mirrors Kendrick and Grossman's (1980) notion that productivity growth rates decelerate before business cycles peak (expansion periods are highlighted by the shaded areas). Appendix C presents further statistics for the productivity development; in line with Kendrick and Grossman (1980) we show median TFP change rates separately for expansion and contraction periods. Over the total sample period, we observe significant differences when using median (approximately 30% improvement in productivity) or mean values (approximately 100% improvement in productivity) to compute the productivity index. The index improvement in 1995–2006 based on the mean values (approximately 6% improvement) mirrors Luhnen's (2009) finding of approximately 8% improvement in the German property/liability sector. Mahlberg and Url (2010) find a significantly higher average increase of approximately 17.8% in 1991–2006 on group-level (life and non-life combined).

Price determinants

In Table 3, we investigate the relationship between the price proxy (combined ratio) and its determinants econometrically; a positive (negative) coefficient implies a negative (positive) relationship of the regressor with price. The coefficients of the first two variables accounting for changes in losses are significantly different from zero in Table 3. Interestingly, the sign of all coefficients is positive. This result is counterintuitive given that insurers' premium calculations are based on discounted future losses plus additional loadings for risk bearing and costs.

Table 3 Determinants of price (Equation 1)

Dependent variable: Price (Combined ratio)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$\Delta Loss_{t-1}$	0.0418***	0.0463***	0.0465***	0.0467***	0.0463***	0.0466***	0.0473***	0.0475***	0.0457***	0.0473***	0.0461***
	(0.0100)	(0.0104)	(0.0104)	(0.0103)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)
$\Delta Loss_{t-2}$	0.0272***	0.0310***	0.0312***	0.0305***	0.0311***	0.0314***	0.0314***	0.0316***	0.0301***	0.0314***	0.0300***
	(0.0089)	(0.0096)	(0.0096)	(0.0096)	(0.0097)	(0.0097)	(0.0096)	(0.0097)	(0.0094)	(0.0096)	(0.0095)
$\Delta Loss_{t-3}$	0.0101	0.0130	0.0131	0.0120	0.0132	0.0133	0.0129	0.0130	0.0119	0.0130	0.0121
	(0.0094)	(0.0098)	(0.0097)	(0.0098)	(0.0098)	(0.0098)	(0.0098)	(0.0098)	(0.0097)	(0.0098)	(0.0097)
Firm capacity$_{t-1}$	-0.0165***	-0.0172***	-0.0171***	-0.0171***	-0.0172***	-0.0172***	-0.0171***	-0.0163***	-0.0118***	-0.0162***	-0.0095**
	(0.0028)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0029)	(0.0034)	(0.0027)	(0.0039)
Industry capacity$_{t-1}$		-0.0811***	-0.0799***	-0.0797***	-0.0816***	-0.0807***	-0.0777***	-0.0776***	-0.0774***	-0.0772***	-0.0774***
		(0.0074)	(0.0078)	(0.0073)	(0.0075)	(0.0075)	(0.0078)	(0.0078)	(0.0077)	(0.0077)	(0.0077)
Financial quality$_{t-1}$	-0.0594**	-0.0583**	-0.0579**	-0.0571**	-0.0584**	-0.0582**	-0.0565**	-0.0549**	-0.0484*	-0.0533**	-0.0483*
	(0.0271)	(0.0270)	(0.0271)	(0.0270)	(0.0270)	(0.0270)	(0.0271)	(0.0266)	(0.0262)	(0.0267)	(0.0270)
ΔTFP_{t-1}	-0.0048	-0.0018	-0.0018	-0.0018	-0.0017	-0.0015	-0.0016	-0.0018	-0.0005	-0.0024	-0.0028
	(0.0070)	(0.0109)	(0.0109)	(0.0107)	(0.0109)	(0.0108)	(0.0106)	(0.0107)	(0.0107)	(0.0110)	(0.0107)
Size$_{t-1}$	0.0059	0.0149**	0.0152**	0.0163**	0.0142**	0.0120	0.0116	0.0116	0.0115	0.0118	0.0117
	(0.0098)	(0.0064)	(0.0064)	(0.0064)	(0.0063)	(0.0075)	(0.0074)	(0.0074)	(0.0075)	(0.0074)	(0.0075)
Size$^2_{t-1}$	-0.0033	-0.0032	-0.0027	-0.0034	-0.0035	-0.0041	-0.0043	-0.0044	-0.0039	-0.0043	-0.0045
	(0.0056)	(0.0055)	(0.0055)	(0.0055)	(0.0056)	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0056)	(0.0054)
Mutual$_{t-1}$	0.0177	0.0160	0.0147	0.0150	0.0172	0.0208	0.0214	0.0217	0.0208	0.0206	0.0219
	(0.0516)	(0.0517)	(0.0517)	(0.0517)	(0.0518)	(0.0510)	(0.0509)	(0.0508)	(0.0507)	(0.0511)	(0.0510)
Public$_{t-1}$	-0.0142	-0.0156	-0.0167	-0.0161	-0.0145	-0.0124	-0.0119	-0.0117	-0.0126	-0.0113	-0.0117
	(0.0165)	(0.0147)	(0.0147)	(0.0147)	(0.0148)	(0.0154)	(0.0154)	(0.0154)	(0.0151)	(0.0156)	(0.0151)
Insurance penetration$_{t-1}$		-1.4934	-1.1201	-2.3402	-2.0006	-1.2858	-2.3093	-2.3169	-2.1971	-2.3624	-2.2669
		(1.8594)	(1.9853)	(1.8905)	(2.0579)	(1.8515)	(2.0874)	(2.0883)	(2.0613)	(2.0931)	(2.0978)
Competition$_{t-1}$		-0.6055	-0.5614	-0.7641	-0.6989	-0.5966	-0.8424*	-0.8299*	-0.8071*	-0.8284*	-0.8291*
		(0.4737)	(0.4831)	(0.4678)	(0.4897)	(0.4713)	(0.4757)	(0.4758)	(0.4726)	(0.4758)	(0.4772)
ΔInterest rate$_{t-1}$			0.2080				0.3705	0.3600	0.3828	0.3672	0.3815*
			(0.1982)				(0.2286)	(0.2306)	(0.2347)	(0.2273)	(0.2279)
Catastrophic year$_{t-1}$				-0.0162***			-0.0160***	-0.0162***	-0.0161***	-0.0163***	-0.0159***
				(0.0049)			(0.0049)	(0.0049)	(0.0048)	(0.0049)	(0.0049)
GDP$_{t-1}$					-0.0978		-0.1791	-0.1809	-0.1753	-0.1913	-0.1821
					(0.1074)		(0.1242)	(0.1238)	(0.1254)	(0.1229)	(0.1241)
Regulation$_{t-1}$						-0.0072	-0.0099	-0.0103	-0.0101	-0.0096	-0.0098
						(0.0107)	(0.0108)	(0.0108)	(0.0108)	(0.0107)	(0.0108)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$								0.2697*			
								(0.1623)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$									-0.0192***		
									(0.0053)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$										0.2392***	
										(0.0888)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$											-0.0097**
											(0.0043)
Unit dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	No	No	No	No	No	No	No	No	No
Observations	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

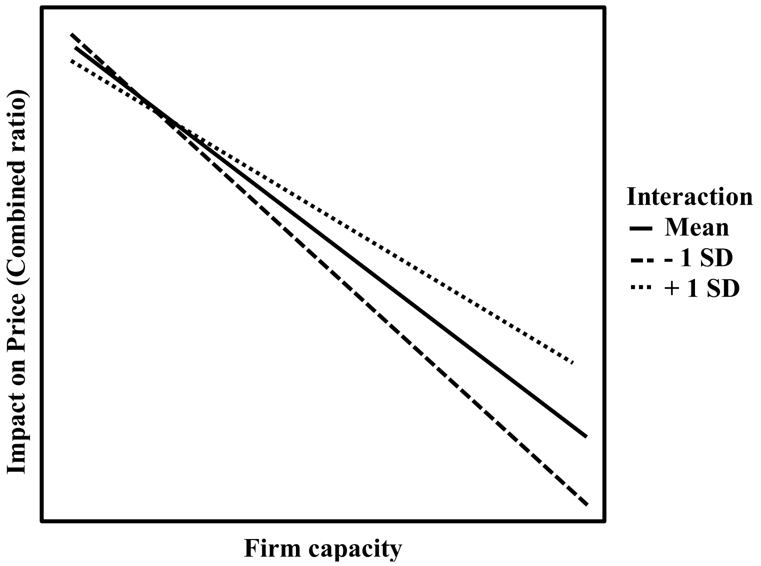
This suggests a negative coefficient since insurers should alter their forecasts based on historical loss experiences. Cummins and Danzon (1997) confirm an inverse relationship between prices and loss shocks consistent with their model. One possible explanation for this result is that, on average, the pricing in the German non-life market is oriented more to strategic (e.g., distribution and marketing considerations) than to actuarial aspects in competition for customers. For example, Eling and Luhnen (2008) show that German motor insurance historically has gone through several periods of intense competition.

The premiums-to-capital ratio is the basis for our firm and industry capacity variables; an increase in these variables indicates less available capacity and more binding capacity constraints (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015). Table 3 shows consistently significant and negative coefficients for both the firm and industry capacity variables in all models. Thus, we find empirical evidence for H1a and H1b suggesting that increases in the lagged capacity variables have a positive impact on price in line with the capacity-constraint hypothesis of Gron (1994) and Winter (1994). This result is also in line with the empirical findings of Weiss and Chung (2004) for a sample of U.S. property-casualty reinsurers. Subsequent to the contradictory findings of Cummins and Danzon (1997), we can thus confirm the anticipated role of capacity in firm-level data of primary non-life insurers. In addition, Table 3 reports significant and negative coefficients of the financial quality variables in all models. This result lends support to the risky-debt hypothesis (Cummins & Danzon, 1997; Weiss & Chung, 2004) meaning that improved financial quality of the insurer (i.e., less leverage) has a positive impact on price.

Table 3 provides no evidence of a relationship between the lagged productivity change variable and the price proxy. Although theoretic considerations suggest interactions among price and productivity (Grifell-Tatjé & Lovell, 2015), these interactions may occur contemporaneously and not dynamically (Footnote 14). Other firm characteristics seem to play a minor role; only, the coefficient of the firm size variable is significant and positive in some of the models presented in Table 3.

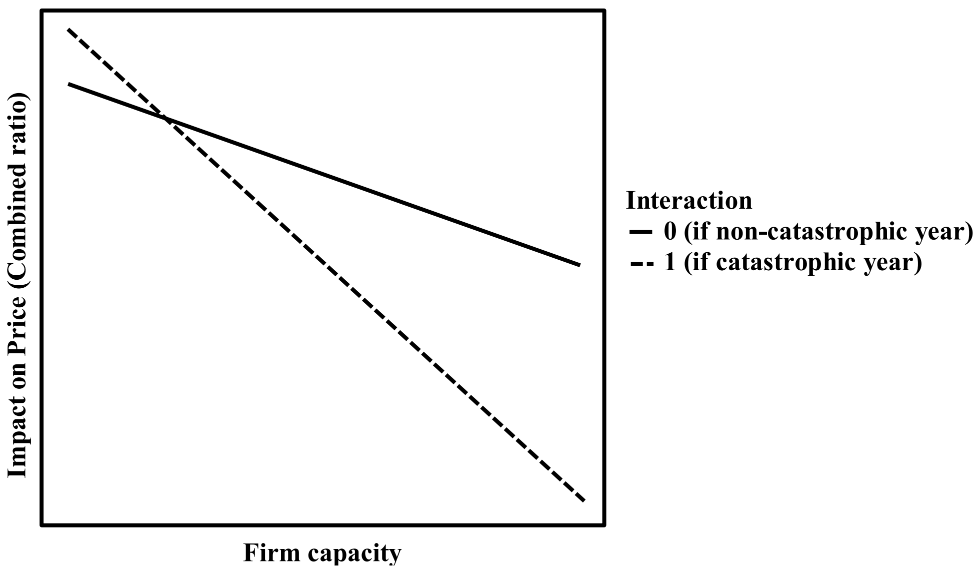
Table 3 provides evidence for moderation of the capacity-price relationship by exogenous factors (H1c). In Model (8), the coefficient of the interaction term between the firm capacity and interest rate change variables is significant (positive moderation). Figure 2 illustrates that if ΔInterest rate$_{t-1}$ decreases by one standard deviation (SD) from its mean level, the line slope becomes steeper, meaning price is more sensitive to firm capacity. This is in line with the notion that a negative interest rate shock adversely affects all firms in the market, increasing the pressure to replenish capital via increased prices (Doherty & Garven, 1995).[15]

Figure 2 Interaction between interest rate change and firm capacity



In Model (9), the coefficient of the interaction term between the firm capacity and catastrophic year variables is significant (negative moderation). Figure 3 shows that if a catastrophic year occurs (lagged catastrophic year variable takes value 1), the impact of the firm capacity variable on the combined ratio in the next year becomes more negative. This supports the expectation that following adverse market loss shocks, insurers increase prices in order to replenish capital (Gron, 1994; Winter, 1994; Weiss, 2007).

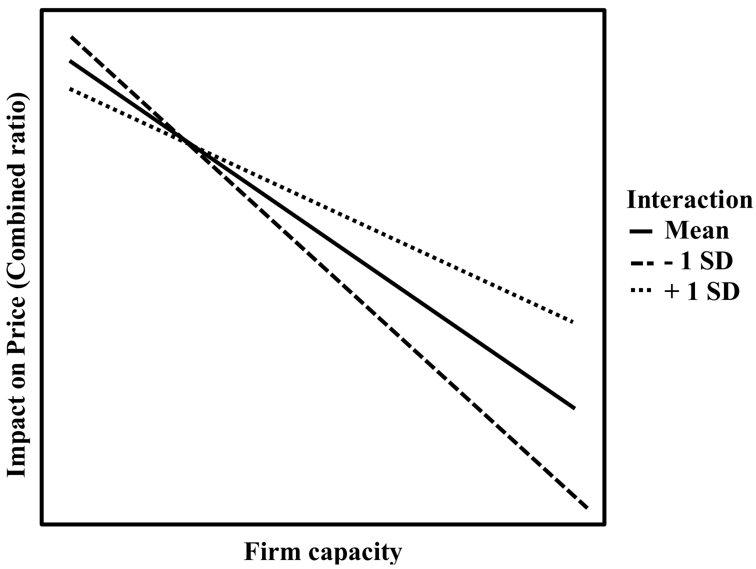
Figure 3 Interaction between catastrophe and firm capacity



[15] Insurer capital is prone to interest rate changes if an asset-liability mismatch prevails (Weiss, 2007). Since all companies within a single market face the same change in the interest rate and given that asset-liability structures are similar, the relative position of the insurer in terms of its financial quality is unaffected by an interest rate change but the decrease in the interest rate leads, *ceteris paribus*, to a symmetric deterioration of the capital basis among all insurers.

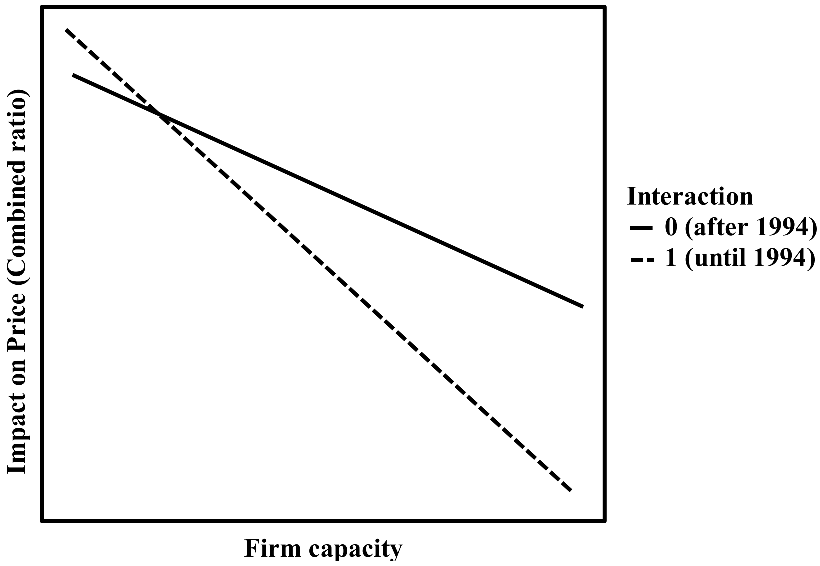
In Model (10), the coefficient of the interaction term between the firm capacity variable and GDP growth is significant (positive moderation). Figure 4 illustrates that if GDP growth falls (increases) by one SD below (above) its mean level, the line slope becomes steeper (less steep) meaning price is more (less) sensitive towards firm capacity in this situation. Thus, if GDP growth falls below (above) its mean level, the role of capacity constraints seem to become more (less) relevant for insurers' decisions to increase prices in the next year. This result contradicts our prior expectation of a more significant role of capacity constraints during expansion periods. One explanation for this result is that insurers with constrained capacity use particularly downturns to increase their capital basis for the next expansion period. The result may also be driven by the fact that capital might be less scarce and, therefore, cheaper during expansionary periods; conversely, insurers with constrained capacity may increase prices to build up internal capital during contraction periods with scarce and expensive capital.

Figure 4 Interaction between GDP growth and firm capacity



In Model (11), the coefficient of the interaction term between the firm capacity and regulation variables is significant (negative moderation). Figure 5 illustrates that the line slope is steeper pre-deregulation (and pre-Solvency II). This result could be related to the possibility that high levels of price regulation, as it was the case in Germany before 1994, limit the flow of capital to the insurance industry. Our result can be set in reference with Bruneau and Sghaier (2015), who also find that capacity constraints were a bigger concern in the French property-liability insurance sector prior to 1995; however, as noted above, France had already traditionally been subject to low insurance regulation. The post-deregulation period overlaps with the efforts of increased capital regulation starting with the launching of the formal legislative process for Solvency II in 2007. Thus, our result could also emphasize, that (firm-specific) capacity is a less important price determinant due to increased capital regulation.

Figure 5 Interaction between regulation and firm capacity



Appendix E shows the price regression models with the interaction effects separately for hard and soft market periods, which were defined according to Appendix E. The coefficients of the industry capacity variable are significant and negative in all models of the hard-market and soft-market samples. With only three exceptions, the coefficients of the firm-capacity variable are negative and significant in all models. In the hard-market sample, the coefficients of the interaction terms between the firm-capacity variable and the interest rate change as well as the catastrophic year variables are significant and show the expected signs. The coefficients of GDP growth and regulation interaction terms are insignificant. This result could emphasize that capacity constraints evolve at the end of soft market periods and decline at the end of hard market periods (Weiss, 2007); these transitions may not be modelled if hard markets are separated from soft markets. Interestingly, in the soft-market sample, the coefficients of the interest rate change and catastrophic year interaction terms show the opposite sign. This could indicate that different rules apply in soft-market periods.

Productivity change determinants

In Table 4, we investigate the relationship between productivity change and its determinants following Cummins and Xie (2013). The coefficients of the firm capacity variable are significant and negative in all regression models. However, all coefficients of the industry capacity variable are insignificant. In Model (3), we consider also quadratic terms of the two capacity variables but their coefficients are insignificant, rejecting the presence of a non-linear relationship. Thus, our results suggest that only firm-specific capacity determines productivity change; positive increases in the deviation of firm-specific capacity from the industry average have a negative impact on productivity change. This result is in line with Cummins and Xie (2013), who also find a negative impact of the premium-to-capital ratio. While the authors conclude that leverage penalties explain the negative impact, we disentangled the financial quality effect from capacity (Section 3.1).

Firms with high premiums-to-capital ratios appear constrained in their ability to increase the outputs-inputs ratio from one period to the other and may even experience negative productivity change. Thus, capacity constraints also seem to be relevant for productivity change, with high premiums-to-capital ratios indicating delayed, hindered, or even negative productivity growth. Grifell-Tatjé and Lovell (2015) formally show that the product of productivity change and price recovery (growth in output prices relative to the growth in input factor prices) together determine profitability change. Thus, given that capacity constraints may cause negative productivity change, insurers, *ceteris paribus*, also have to increase output prices to avoid profitability losses. This helps to explain why insurers raise their prices in times of constrained capacity. Overall, we find support only for H2a, not for H2b.

Interestingly, Table 4 shows statistically significant and negative coefficients for the financial quality variable in all models. Thus, an increase in this variable (reflecting less leverage) penalizes insurers in terms of productivity growth. This contradicts the expectation of the reverse impact, namely that decreased financial quality (increased leverage) negatively affects productivity change (Cummins & Xie, 2013) assuming that lower security levels of the insurer result in decreased output volume as policyholders penalize default risk (Wakker, Thaler, & Tversky, 1997; Epermanis & Harrington, 2006). In another regression model, we test for a non-linear impact of financial quality but the results are insignificant (the results are available upon request). Regarding other firm characteristics, Table 4 shows significant coefficients only for the firm size variable in some models, suggesting a positive impact of size.

Table 4 Determinants of productivity change (Equation 2)

Dependent variable: ΔTFP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Firm capacity$_{t-1}$	-0.0085***	-0.0080***	-0.0071**	-0.0071***	-0.0080***	-0.0080***	-0.0081***	-0.0071***	-0.0076***	-0.0079***	-0.0069***	-0.0066**
	(0.0021)	(0.0021)	(0.0029)	(0.0023)	(0.0021)	(0.0021)	(0.0021)	(0.0023)	(0.0023)	(0.0016)	(0.0021)	(0.0028)
Industry capacity$_{t-1}$		0.0083	0.0005	0.0094	0.0081	0.0085	0.0070	0.0077	0.0077	0.0078	0.0077	0.0077
		(0.0092)	(0.0070)	(0.0099)	(0.0089)	(0.0095)	(0.0093)	(0.0096)	(0.0096)	(0.0095)	(0.0096)	(0.0096)
Financial quality$_{t-1}$	-0.0718***	-0.0650***	-0.0636***	-0.0676***	-0.0654***	-0.0649***	-0.0656***	-0.0681***	-0.0687***	-0.0690***	-0.0675***	-0.0676***
	(0.0212)	(0.0204)	(0.0214)	(0.0176)	(0.0205)	(0.0204)	(0.0204)	(0.0175)	(0.0169)	(0.0173)	(0.0169)	(0.0170)
Price$_{t-1}$	0.0435	0.0412	0.0430	0.0298	0.0412	0.0415	0.0423	0.0306	0.0314	0.0318	0.0317	0.0304
	(0.0300)	(0.0277)	(0.0277)	(0.0290)	(0.0277)	(0.0280)	(0.0276)	(0.0294)	(0.0295)	(0.0289)	(0.0299)	(0.0291)
Size$_{t-1}$	0.0045	-0.0023	-0.0044	-0.0021	-0.0026	-0.0018	0.0074*	0.0044	0.0046	0.0044	0.0044	0.0044
	(0.0053)	(0.0038)	(0.0044)	(0.0037)	(0.0039)	(0.0038)	(0.0040)	(0.0040)	(0.0040)	(0.0039)	(0.0040)	(0.0040)
Size$^2_{t-1}$	-0.0041	-0.0068	-0.0084	-0.0043	-0.0067	-0.0067	-0.0041	-0.0022	-0.0022	-0.0023	-0.0023	-0.0022
	(0.0058)	(0.0057)	(0.0072)	(0.0076)	(0.0056)	(0.0056)	(0.0058)	(0.0074)	(0.0075)	(0.0071)	(0.0075)	(0.0076)
Mutual$_{t-1}$	-0.0333	-0.0218	-0.0202	-0.0226	-0.0215	-0.0225	-0.0360	-0.0325	-0.0331	-0.0325	-0.0323	-0.0325
	(0.0266)	(0.0285)	(0.0287)	(0.0246)	(0.0283)	(0.0287)	(0.0266)	(0.0233)	(0.0234)	(0.0234)	(0.0234)	(0.0233)
Public$_{t-1}$	-0.0090	-0.0028	-0.0006	-0.0047	-0.0026	-0.0035	-0.0135*	-0.0118*	-0.0120*	-0.0117	-0.0120*	-0.0118*
	(0.0067)	(0.0078)	(0.0072)	(0.0070)	(0.0076)	(0.0084)	(0.0074)	(0.0070)	(0.0070)	(0.0072)	(0.0071)	(0.0069)
Insurance penetration$_{t-1}$		0.5874	0.5419	1.7444	0.7272	0.9783	-0.2618	1.3029	1.2571	1.2651	1.3036	1.3047
		(1.5664)	(1.5751)	(1.6899)	(1.5745)	(1.9034)	(1.5724)	(2.0278)	(2.0308)	(2.0528)	(2.0256)	(2.0318)
Competition$_{t-1}$		-0.2424	-0.0066	0.0961	-0.2242	-0.1629	-0.3152	0.0794	0.0617	0.0727	0.0784	0.0800
		(0.4624)	(0.4101)	(0.5109)	(0.4396)	(0.4597)	(0.4696)	(0.4748)	(0.4717)	(0.4747)	(0.4745)	(0.4753)
Firm capacity$^2_{t-1}$			-0.0002									
			(0.0003)									
Industry capacity$^2_{t-1}$			0.0072									
			(0.0073)									
ΔInterest rate$_{t-1}$				0.2967*				0.2206	0.2192	0.2172	0.2223	0.2213
				(0.1653)				(0.1843)	(0.1827)	(0.1804)	(0.1831)	(0.1819)
Catastrophic year$_{t-1}$					0.0037			0.0063	0.0064	0.0063	0.0065	0.0063
					(0.0098)			(0.0103)	(0.0103)	(0.0103)	(0.0104)	(0.0104)
GDP$_{t-1}$						0.0690		0.0006	0.0022	0.0006	0.0017	0.0005
						(0.1664)		(0.1919)	(0.1918)	(0.1919)	(0.1926)	(0.1915)
Regulation$_{t-1}$							0.0240***	0.0176***	0.0180***	0.0176***	0.0174***	0.0176***
							(0.0073)	(0.0066)	(0.0066)	(0.0067)	(0.0067)	(0.0067)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$									-0.2360			
									(0.1533)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$										0.0029		
										(0.0071)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$											-0.0894	
											(0.0890)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$												-0.0007
												(0.0051)
Unit dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	No	No	No	No	No	No	No	No	No	No
Observations	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively.

While Table 4 detects no interactions between the firm capacity and the exogenous variables, the coefficients of the regulation variable are significantly different from zero and have a positive sign in all models.[16] In contrast to Mahlberg and Url's (2010) finding of increased productivity on group level post-deregulation, this result suggests higher productivity change pre-deregulation.

6 Conclusions

We analyze the impact of capacity on price and productivity change in a newly constructed firm-level sample for the German non-life market over the 1954–2016 period. This sample period is much longer than previous studies of insurance cycles. Additionally, we specifically control for insurance demand which has not typically been done in prior studies of insurance cycles. This has been a common criticism of previous analyses of insurance market cycles. Our results support the capacity-constraint hypothesis and emphasize that both firm and industry capacity are relevant price determinants. The impact of capacity on price is complex and depends on exogenous factors (interest rate change, catastrophic years, GDP growth, and regulation). Our results also show that decreased firm capacity has a negative impact on productivity change. Since price and productivity change together determine profitability, insurers may also increase prices to account for negative productivity change as a result of constrained capacity.

Our results yield important implications for the understanding of underwriting cycles and re-emphasize the role of capacity in this context. The impact of capacity is more complex than previously documented and depends on several exogenous factors. The pressure to increase prices due to capacity constraints is reinforced during interest rate declines, catastrophic years, and GDP drops. These results illustrate that the causes of underwriting cycles are even more diverse than previously assumed and highlight that different hard-market phases may have different causes. As described above, these findings represent not only important contributions to the academic literature on insurance cycles, but also to the business of insurance.

The analyses presented here offer numerous directions for future research. The analyses could be expanded to by-line cross-sectional data, which would yield interesting insights about idiosyncrasies of certain business lines. Also, contemporaneous interactions among capacity, prices, and productivity could be analyzed if appropriate instruments are available. In addition, it is of interest whether industry-shocks have the same price/productivity impact or whether differences among (group of) firms can be observed (e.g., by means of a factor augmented vector autoregression). It also could be

[16] Huang and Eling (2013) demonstrate that various economic and industry factors determine productivity change in the non-life insurance industry of the BRIC countries in 2000–2008. Besides the sample differences, differences exist because their analysis relies on a multistage data envelopment analysis (DEA) model and focuses on contemporaneous impacts.

worthwhile to compare the estimated cycle length using industry data compared to using firm-level data. Like previous literature, this study lacks accurate price data and relies on the combined ratio as proxy.

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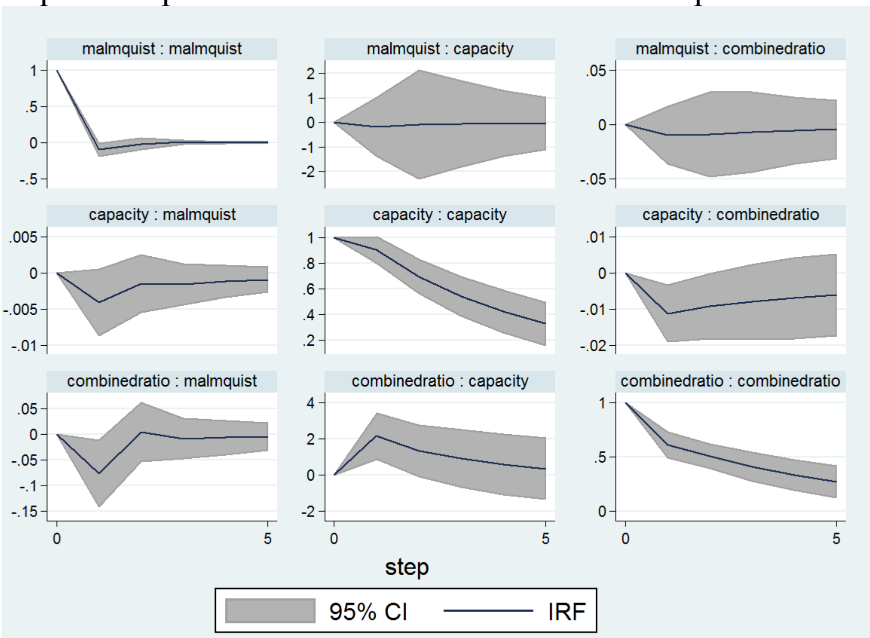
Appendix A
Impulse response functions estimated from linear panel VAR model



Notes: The impulse response functions stem from a linear panel VAR model which analyzes the short-term dynamic interactions among capacity, price and productivity. The model was specified following Bruneau and Sghaier (2015), which analyzes the short-term dynamic interactions between the capacity and the combined ratio at the industry level. We extended this framework by considering also ΔTFP. The model specification is shown in Equation (A1). The model was based on the Arellano-Bond estimator (Arellano & Bond, 1991). The lines illustrated the responses from all variables in the model to a (positive) one standard deviation shock in the impulse variable.

$$X_{i,t} = \alpha_0 + \sum_{i=1}^{P} \alpha_{1,i} X_{i,t-1} + \sum_{i=1}^{P} \alpha_{2,i} X_{i,t-2} + \varepsilon_{i,t}, \quad \text{(A1)}$$

where $X_{i,t} = (Capacity, Combined\ Ratio, \Delta TFPs)$.

Appendix B
Definition of expansion and contraction periods

Reference	Cycle	Trough	Beginning Quarter Expansion	Peak	Beginning Quarter Contraction	Expansion (Trough–Peak)	Contraction (Peak–Trough)
Heilemann & Schuhr (2008)				1955-II (4)	1956-II (9)	1954–1955	1956–1958
	1958-III–1962-IV (18)	1958-III (4)	1959-III (3)	1960-II (5)	1961-III (6)	1959–1960	1961–1962
	1963-I–1966-IV (16)	1963-I (1)	1963-II (6)	1964-IV (3)	1965-III (6)	1963–1964	1965–1967
	1967-I–1971-I (17)	1967-I (4)	1968-I (6)	1969-III (2)	1970-I (5)	1968–1969	1970–1971
	1971-I–1974-I (12)	1971-II (4)	1972-II (2)	1972-IV (2)	1973-II (4)	1972–1972	1973–1975
	1974-II–1982-I (32)	1974-II (7)	1976-I (13)	1979-II (4)	1980-II (8)	1976–1979	1980–1982
			1975-IV (14)				
	1982-II–1994-I (48)	1982-II (6)	1983-IV (27)	1990-III (6)	1992-I (9)	1983–1991	1992–1993
		1982-IV (3)	*1983-II (28)*		*1991-IV (9)*		
	1994-II–2001-IV (31)	1994-II (1)	1994-III (23)	2000-II (5)	2001-III (2)	1994–2000	2001–2003
				2000-I (5)			
	2002-I–2004-II (10)	2002-I (7)	2003-IV (3)	*2008-I (3)*		2004–2007	2008–2009
		2001-IV (8)					
Döhrn (2014)	*2008-IV–2012-III*	*2008-V (5)*	*2010-I (6)*	*2011-III (3)*	*2012-II (2)*	2010–2011	2012–2012
	2012-IV	*2012-IV (2)*				2013–2016	

Notes: Döhrn's (2014) results are italicized. Numbers in parentheses show duration of cycle phase in quarters.

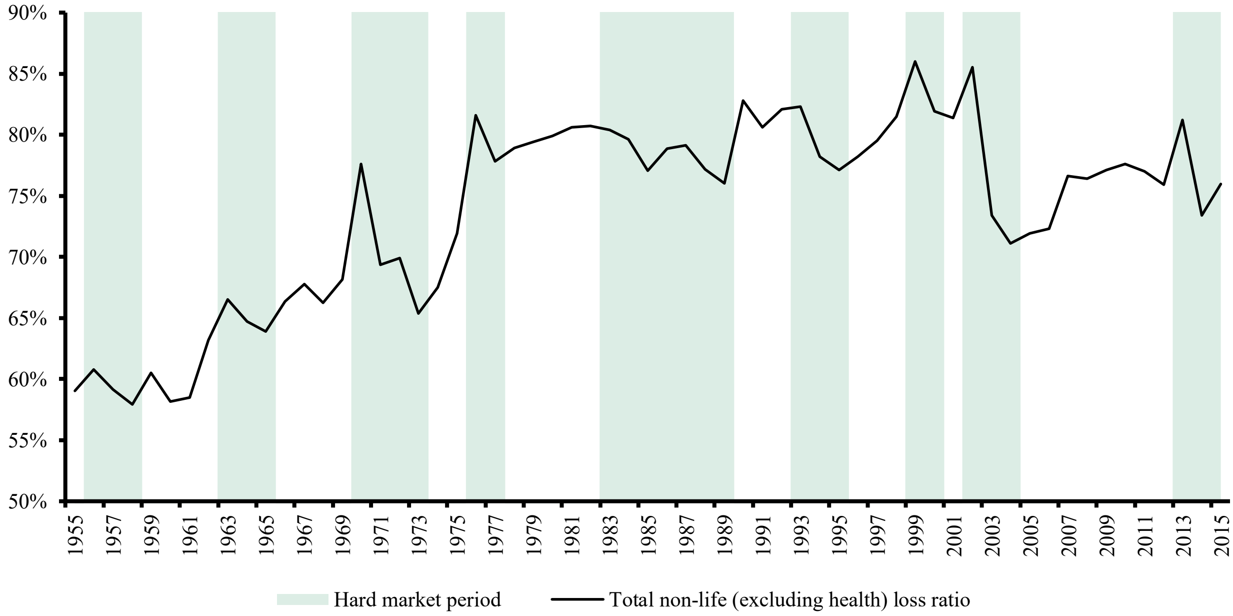
Appendix C

Median annual productivity change rates over the German business cycle

Period	Median ΔTFP	Period	Median ΔTFP
Expansion (Trough–Peak)		Contraction (Peak–Trough)	
1954–1955	1.0211	1956–1958	1.0061
1959–1960	1.0127	1961–1962	0.9966
1963–1964	1.0056	1965–1967	0.9993
1968–1969	1.0062	1970–1971	1.0060
1972–1972	1.0299	1973–1975	1.0099
1976–1979	0.9989	1980–1982	1.0040
1983–1991	1.0014	1992–1993	1.0037
1994–2000	1.0014	2001–2003	0.9974
2004–2007	1.0068	2008–2009	1.0016
2010–2011	1.0057	2012–2012	0.9981
2013–2016	1.0059		1.0029
Total	1.0030	Total	1.0029
Complete period			
1955–2016	1.0032		

Notes: Kendrick and Grossman (1980) find that during expansion (contraction) periods, productivity shows stronger (weaker) growth in various U.S. industries. Appendix C replicates their analysis for the German non-life insurance sector using the business cycle phase definitions from Table Appendix B. Based on the results, we cannot confirm these findings of Kendrick and Grossman for the German non-life insurance sector; the median TFP change rates are only marginally different. However, Appendix C shows that negative TFP change is more common in contraction periods than in expansion periods.

Appendix D
Definition of hard market periods



Notes: Appendix D shows the development of the loss ratio for the complete German non-life sector (excluding health). Data is obtained from the annual reports of the German Federal Financial Supervisory Authority; the loss ratio is used since expenses data are available only after 1975. Hard market phases start at the peak of the loss ratio development and end at the trough. Furthermore, the loss ratio must have decreased by more than 3% in this period in order to be classified as hard market period.

Appendix E
Price determinants in soft and hard market periods

Dependent variable: Price (Combined ratio)	Hard market periods					Soft market periods				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\Delta Loss_{t-1}$	0.0084	0.0093	0.0082	0.0081	0.0083	0.0379**	0.0385***	0.0380**	0.0378**	0.0378**
	(0.0076)	(0.0076)	(0.0075)	(0.0075)	(0.0076)	(0.0149)	(0.0148)	(0.0149)	(0.0149)	(0.0149)
Firm capacity$_{t-1}$	-0.0076***	-0.0060**	0.0022	-0.0061**	-0.0060	-0.0136***	-0.0151***	-0.0194***	-0.0135***	-0.0074
	(0.0029)	(0.0028)	(0.0031)	(0.0028)	(0.0039)	(0.0029)	(0.0036)	(0.0049)	(0.0031)	(0.0062)
Industry capacity$_{t-1}$	-0.0522***	-0.0524***	-0.0512***	-0.0520***	-0.0522***	-0.0474***	-0.0485***	-0.0481***	-0.0473***	-0.0470***
	(0.0088)	(0.0087)	(0.0084)	(0.0088)	(0.0088)	(0.0076)	(0.0077)	(0.0077)	(0.0076)	(0.0076)
Financial quality$_{t-1}$	0.0188	0.0141	0.0281	0.0246	0.0196	-0.0220	-0.0322	-0.0323	-0.0212	-0.0147
	(0.0216)	(0.0216)	(0.0220)	(0.0221)	(0.0213)	(0.0397)	(0.0426)	(0.0423)	(0.0406)	(0.0414)
ΔTFP_{t-1}	0.0010	0.0014	0.0052	0.0006	0.0008	-0.0526	-0.0494	-0.0495	-0.0528	-0.0541
	(0.0092)	(0.0093)	(0.0090)	(0.0094)	(0.0093)	(0.0357)	(0.0350)	(0.0350)	(0.0355)	(0.0365)
Size$_{t-1}$	0.0055	0.0047	0.0040	0.0056	0.0056	0.0217***	0.0224***	0.0217***	0.0217***	0.0218***
	(0.0103)	(0.0102)	(0.0101)	(0.0104)	(0.0103)	(0.0077)	(0.0078)	(0.0077)	(0.0077)	(0.0077)
Size$^2_{t-1}$	-0.0043	-0.0039	-0.0016	-0.0046	-0.0043	0.0032	0.0033	0.0026	0.0032	0.0030
	(0.0055)	(0.0056)	(0.0057)	(0.0055)	(0.0055)	(0.0052)	(0.0052)	(0.0053)	(0.0052)	(0.0052)
Mutual$_{t-1}$	0.0009	0.0023	0.0003	0.0016	0.0009	0.0176	0.0159	0.0180	0.0175	0.0182
	(0.0511)	(0.0514)	(0.0512)	(0.0513)	(0.0511)	(0.0368)	(0.0369)	(0.0372)	(0.0368)	(0.0367)
Public$_{t-1}$	-0.0238	-0.0221	-0.0250	-0.0239	-0.0238	-0.0247	-0.0243	-0.0233	-0.0247	-0.0244
	(0.0165)	(0.0165)	(0.0165)	(0.0165)	(0.0165)	(0.0242)	(0.0245)	(0.0242)	(0.0242)	(0.0244)
Insurance penetration$_{t-1}$	-7.2900**	-7.2948**	-6.4759**	-7.2850**	-7.3051**	6.5726***	6.4519***	6.3135***	6.5770***	6.6629***
	(3.2235)	(3.1929)	(3.0429)	(3.2323)	(3.2254)	(2.2235)	(2.2497)	(2.2787)	(2.2219)	(2.2195)
Competition$_{t-1}$	-1.8590***	-1.8861***	-1.7025***	-1.8452***	-1.8561***	-1.2310**	-1.3235**	-1.2730**	-1.2281**	-1.2181**
	(0.5901)	(0.5899)	(0.5819)	(0.5944)	(0.5916)	(0.5768)	(0.5984)	(0.5948)	(0.5788)	(0.5781)
ΔInterest rate$_{t-1}$	0.0717	0.0064	0.1206	0.0798	0.0748	-0.6809**	-0.7651***	-0.6728***	-0.6803**	-0.6770**
	(0.3319)	(0.3233)	(0.3460)	(0.3347)	(0.3346)	(0.2714)	(0.2681)	(0.2561)	(0.2722)	(0.2711)
Catastrophic year$_{t-1}$	-0.0372***	-0.0375***	-0.0370***	-0.0371***	-0.0371***	0.0232***	0.0229***	0.0236***	0.0232***	0.0234***
	(0.0069)	(0.0067)	(0.0064)	(0.0068)	(0.0069)	(0.0068)	(0.0064)	(0.0066)	(0.0068)	(0.0068)
GDP$_{t-1}$	-0.5153*	-0.5039*	-0.5262*	-0.5105*	-0.5189*	-0.2540**	-0.2399*	-0.2684**	-0.2536**	-0.2484*
	(0.3039)	(0.3029)	(0.3019)	(0.3032)	(0.3072)	(0.1293)	(0.1301)	(0.1291)	(0.1289)	(0.1295)
Regulation$_{t-1}$	-0.0396***	-0.0401***	-0.0410***	-0.0407***	-0.0396***	0.0261**	0.0296**	0.0258**	0.0260**	0.0259**
	(0.0131)	(0.0131)	(0.0131)	(0.0133)	(0.0131)	(0.0118)	(0.0121)	(0.0117)	(0.0118)	(0.0119)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$		0.7109***					-0.6820***			
		(0.1731)					(0.2051)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$			-0.0355***					0.0196***		
			(0.0066)					(0.0065)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$				-0.1750					0.0193	
				(0.1273)					(0.0744)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$					-0.0019					-0.0071
					(0.0045)					(0.0054)
Unit dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Observations	2,635	2,635	2,635	2,635	2,635	2,384	2,384	2,384	2,384	2,384

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively.

Part IV

Stock versus Mutual Insurers: Long-Term Convergence or Dominance?

PHILIPP SCHAPER

Abstract

I find evidence for convergence of stock and mutual insurers in an analysis of metatechnology efficiency estimated by data envelopment analysis in samples for the U.S. and EU from 2002 to 2015. This result may emphasize that, contrary to findings of previous literature, the dominance of the two organizational forms declines over time. Recent changes in the economic environment (for example, elimination of state aids for the mutual organizational form and introduction of risk-based capital standards) may explain this result. Unlike previous studies focusing on the expense preference and efficient structure hypotheses, I consider the dynamics of stock and mutual insurers' technology and efficiency.

Keywords: Organizational form · Efficiency · Metafrontier data envelopment analysis · Insurance

JEL classification: D23 · G22 · L23

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1 Introduction

The efficiency implication of the organizational form is a subject of great interest in the literature. Particularly in a long-term perspective, this question is important because the coexistence of both forms is presumably advantageous for the market as a whole (Michie & Llewellyn, 2010; Broek, Buiskool, Grijpstra, & Plooij, 2011); for example, mutual insurers are assumed to perform better during crises. In the past, some states in the United States (US) and some countries in the European Union (EU) even supported mutual insurers by requiring less capital and offering tax incentives (Zanjani, 2007; Broek et al., 2011). Prior insurance literature (see, e.g., Braun, Schmeiser, & Rymaszewsk (2015) for a recent review) found much empirical support during the 1980s and 1990s for the hypothesis that the stock and mutual organizational forms are each dominant in different market segments, leading to the conclusion that the two forms apply different production technologies (i.e., the efficient structure hypothesis, or ESH).[1] Conversely, the hypothesis that the stock organizational form is—in direct comparison with the mutual form—dominant in terms (cost) efficiency (i.e., the expense preference hypothesis, EPH) has not gained much empirical support.

Since the 1990s, the economic context for stock and mutual insurers has changed in the two largest insurance markets—the U.S. and EU—giving rise to expect changes particularly in the way mutual insurers operate (Broek et al., 2011). The EU has begun to eliminate state aids (e.g., tax incentives, lower capital requirements) for the mutual organizational form in 2000. Also, the U.S. has largely aligned the solvency regulations for the two organizational forms (Zanjani, 2007). These actions were taken to level the organizational playing field. Furthermore, the increased focus on risk-based capital requirements—in place in the U.S. since the early 1990s—in the EU under Solvency II gives insurers incentives to diversify across various lines of business. Subsequently, niche players or specialized insurers will most likely face competition from larger and diversified insurers that attain economies of scale and scope. Moreover, the operating environment, especially in the EU, has become more homogenous due to reduced trade barriers through the European Internal Market (Cummins, Rubio-Misas, & Zi, 2016). In addition, developments such as low interest rates and market saturation have increased the pressure to improve efficiency in the insurance sector (see, e.g., Eling & Schaper, 2017). A relevant question is how stock and mutual insurers operate over the long term in this changed environment.

[1] *Production technology* is defined as the operational practices (i.e., the management activities subject to other factors such as available human capital and economic infrastructure) that determine how inputs are transformed into outputs. It is derived from the firms within a group that have the highest input-output combinations, thus constituting also the efficient frontier, and highlights what is feasible for all firms in this group. Efficiency measures the productivity of a firm in the group relative to the efficient frontier. Technologies across groups of firms (e.g., different industries, regions, or countries) can differ because each group may face different production opportunities (which could be simply because they operate in different environments) and consequently uses different input-output combinations (O'Donnell, Rao, & Battese, 2008).

The purpose of this article is to analyze long-term trends in the technology use of stock and mutual insurers with special attention to the relevant developments in the operating environment. By considering the changed economic environment, I hypothesize that mutual and stock insurers' production processes converge over time (i.e., the convergence hypothesis). In samples for the U.S. and EU markets, I analyze trends of metatechnology efficiency estimated by data envelopment analysis (DEA) in 2002–2015 using the concepts of β- and σ-convergence (O'Donnell, Rao, & Battese, 2008; Cummins et al., 2016). Metatechnology efficiency is the ratio of efficiency measured against a common benchmark (the metafrontier) constituting insurers from both organizational forms to the efficiency measured against a group-specific benchmark. If efficiency levels from both frontiers are equal, the metatechnology ratio is 1, indicating that stock and mutual insurers use the same technologies. Conversely, levels lower than 1 indicate technology differences. β-convergence econometrically measures the catch-up effect of insurers with the highest technology gaps and σ-convergence measures the dispersion of technologies across insurers (Casu & Girardone, 2010; Cummins et al., 2016).

During the sample period, stock and mutual insurers on average close the gap between individual group frontiers and the common frontier particularly in the EU, revealing some support for my expectation of converging stock and mutual insurers' technologies. In the U.S. sectors, average metatechnology efficiency levels are already quite high at the beginning of the sample period, suggesting only minor production differences between the stock and mutual organizational form. The levels tend to persist until the end of the sample period. Nevertheless, the econometric results (β- and σ-convergence) suggest convergence in both the U.S. and EU. However, these results also indicate that convergence may not be perfect. This conclusion is intuitive given that inherent differences among the organizational forms continue to exist (e.g., the speed to raise capital). Nevertheless, a significant degree of convergence as documented in this study might be the inevitable consequence of risk-based capital standards and the elimination of state protection of the mutual organizational form.

This study contributes a new hypothesis on how stock and mutual insurers operate in the insurance market; it also explains why both organizational forms continue to coexist. While existing theories can explain temporary variations in efficiency across organizational forms in the 1980s and 1990s, in the current operating environment the organizational forms may inevitably have to converge. Analyzing efficiency trends paints a more sustainable picture of firm efficiency because efficiency is not a steady state (see, e.g., Viswanathan & Cummins, 2003). In other words, when assessing efficiency only over a certain period, the corresponding temporal context (e.g., the conditions of the operating environment) should be considered. Otherwise, the efficiency analysis may reveal a biased picture. The remainder of the paper is organized as follows. In Section 2, I review the background and present my hypotheses. Section 3 presents the data and methodology. Section 4 discusses the empirical results and Section 5 concludes.

2 Background and hypothesis development

Prior literature has argued for the dominance of organizational forms in terms of efficiency subject to different reasoning.[2] The EPH states that mutual insurers will be less (cost) efficient than stock insurers due to their weaker control mechanisms of the firm management (Cummins et al., 2004). Whilst the EPH is appealing from a theoretical point of view, it has not gained much empirical support. Evidence for this hypothesis is rather scarce (see, e.g., Cummins, Weiss, & Zi, 1999; Erhemjamts & Leverty, 2010) and most of the literature either finds no support (see, e.g., Gardner & Grace, 1993; Cummins & Zi, 1998; Cummins et al., 2004; Biener & Eling, 2012) or finds mutual insurers to be more efficient than stock insurers (see, e.g., Biener, Eling, & Wirfs, 2016; Eling & Schaper, 2017). Furthermore, the EPH does not explain why both organizational forms coexist on the market.

The ESH predicts that stock and mutual insurers coexist because they perform well in different market segments due to different requirements of managerial discretion and access to capital (Biener & Eling, 2012). The two organizational forms arguably produce different insurance outputs and the stock production technology dominates the mutual production technology for producing stock output and vice-versa. Mutual insurers are expected to succeed in less complex and less risky lines of business which require less managerial discretion and thus less control (Biener & Eling, 2012). Moreover, it is argued that mutual insurers have a competitive advantage in lines of business with relatively long payout periods due to lower incentives to exploit policyholders' interests (Cummins et al., 1999). In contrast to the EPH, the ESH has gained much empirical support. Cummins et al. (1999) find support for the ESH in an analysis of technical and cost efficiency for a sample of U.S. property/liability (p/c) insurers from 1981 to 1991. Cummins et al. (2004) also find support for the hypothesis in a sample of all licensed Spanish insurers from 1989 to 1997: the authors therefore conclude that stock and mutual insurers tend to operate on separate production, cost, and revenue frontiers.

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2 Agency theory has been the central consideration for the efficiency discussion of insurers with different organizational forms. In line with agency theory, the stock and mutual forms both have inherent costs and benefits that determine the financial and operational performance. The inherent disadvantage of the mutual form are less effective control mechanisms of managers because policyholders control less effectively compared to stockholders (Jeng, Lai, & McNamara, 2007). As a consequence, managers of mutual companies may exhibit expense preference behavior (Mester, 1989) and hence may indulge in excessive expenditures on unnecessary staff, emoluments, and other perquisites (Williamson, 1963). Due to this managerial opportunism, mutual companies may choose suboptimal input/output combinations or employ outdated technologies (Cummins, Rubio-Misas, & Zi, 2004). Although mutual insurers have lower control over the manager/owner conflict, they tend to have more control over the customer/owner conflict as mutual insurers unify both roles and thus eliminate any costs related to this conflict (Biener & Eling, 2012).

If stock and mutual insurers continue to produce different outputs (e.g., dominance in different market segments continues in line with the ESH), I do not expect convergence but rather the dominance of different technologies, which is my initial hypothesis (H1a):

H1a: Over the long term, different technologies among stock and mutual insurers dominate.

Although the ESH has gained much empirical support in early studies, in more recent samples for the Northern American and European markets for 2002–2006, Biener and Eling (2012) can find support only for the ESH in a combined world frontier and some selected market segments (i.e., European life production frontier, Northern American non-life cost frontier). To the best of my knowledge, no study has so far assessed whether a state of different production technologies is persistent or changes over time. Since the 1990s, the economic context for stock and mutual insurers has changed, which may affect particularly the practices of mutual insurers for producing insurance outputs and which contribute to convergence of the two organizational forms (Broek et al., 2011).[3] Table 1 provides an overview of the most important changes for the two largest insurance markets—the EU and US. These changes will be discussed in more detail.

[3] The goal of this paper is not to identify the direct causes (economic changes) of convergence trends, if any, as, to my knowledge, no methodological framework is available to realize this. Rather, as previous literature on convergence (e.g., Casu & Girardone, 2010; Cummins et al., 2016), the goal is to detect convergence trends and to present theoretical considerations that may explain convergence in a specific period. However, this also means that if any convergence trends can be observed, the direct causes/importance of the causes remain undetected, which is one of the main limitations of this analysis. Since it is also difficult to assess how the presented arguments affect individual states/countries and how this in turn affects the results for the US and EU, I consider country-fixed effects in all econometric analyses (see also Footnote 4).

Table 1 Overview of Changing Economic Context

Change	Specification
Alignment of legislation for mutual and stock insurers to create a level playing field for every organizational form.	US: Gradual elimination of solvency requirement differentials between stock and mutual insurers. By 2000, only two states in the U.S. still had preferential solvency requirements for mutual insurers (Zanjani, 2007). EU: Harmonization of legislation at the EU level and various rulings to eliminate state aids for the mutual organizational form since the turn of the millennium (e.g., tax advantages, less rigorous solvency regulation) which were previously granted by national laws (Broek et al., 2011).
Introduction of risk-based capital requirements to promote diversification of investments and lines of businesses.	US: Introduction of the Risk-Based Capital (RBC) system for life insurers in 1993, p/c insurers in1994, and health insurers in 1998. EU: Launching of the formal legislative process for Solvency II in 2007 with a transition period starting in 2016.
Creation of a unified European market to increase competition, diversification, enhance products and services, and increase pressure on prices and profit margins.	EU: Introduction of the EU Internal Market in 1993, which has caused convergence in the European market (Cummins et al., 2016).

Because of EU-wide insurance legislation (e.g., the Directives 2002/83/EC for life and 88/357/EEC for non-life insurers) various competitive advantages previously granted by national laws in some member countries for the mutual organizational form were identified as state aid and eliminated (Broek et al., 2011). These actions by the EU ruling bodies were taken to establish a level playing field within the insurance business for all organizational forms. One important contributor to an equal treatment of both organizational forms was the gradual elimination of mutual insurers' preferential tax treatments since 2000 (Mossialos & Thomson, 2009; Broek et al., 2011).[4]

[4] For example, France, Luxembourg, and Belgium had significantly favored mutual insurers over stock insurers (Broek et al., 2011). All three countries account for a major part of the insurance business written by mutual insurers in the EU (ICMIF, 2016). Since information for other countries are hard to obtain and/or the situation may differ among countries, I control for country fixed effects in the later econometric analyses.

Probably the most important action was the elimination of preferential solvency requirements for mutual insurers (Mossialos & Thomson, 2009; Broek et al., 2011).[5] Similar to the EU case, the latest capital regulations in the U.S. have largely ceased to differentiate between organizational forms (for a detailed overview of the state legislatures see National Association of Insurance Commissioners (NAIC), 2010).[6] Thus, under the latest capital regulations in the EU and US, stock and mutual insurers have the same operating conditions.

The aspiration to create a level playing field is expected to have significant implications for mutual insurers' operations. Zanjani (2007) shows that the evolution of the organizational forms in the U.S. life insurance sector depended on the solvency regulation in place. The mutual form could only dominate in states where the capital requirements were favorable. Because equity capital is one of the central inputs in insurer efficiency measurement (Cummins & Weiss, 2013), lower capital requirements represent a major efficiency advantage. Thus, mutual insurers could *ceteris paribus* even afford managerial slack (e.g., due to expense preference behavior) without being identified as an inefficient organizational form. However, this advantage has been eliminated and mutual insurers can now be benchmarked with stock insurers and are consequently exposed to their competition.

In line with the ESH, many mutual insurers in the EU had tended to focus on niche markets or specialize in undertaking selective types of risks (Broek et al., 2011). However, particularly due to Solvency II, for which the formal legislative process was launched in 2007 and which took effect in January 2016, a specialization only one or a few segments becomes difficult.[7] This is because Solvency II calls not only for higher solvency margins but also promotes increased risk diversification. Consequently, specialized insurers must hold more equity than diversified insurers.[8] In addition, the RBC system in the U.S. promotes diversification by assuming correlations among business lines less than one. Given that diversified insurers must hold less equity capital, they may have a competitive advantage to enter new market segments which were

[5] For example, mutual insurers in France had operated under the special Code de la Mutualité, which generally led to less rigorous solvency requirements. Following a ruling of the European Court of Justice in 1999 and infringement proceedings of the European Commission resulted in tightened solvency requirements for mutual insurers in accordance with European rules on the Internal Market and competition (Mossialos & Thomson, 2009). Similar rulings occurred in Belgium in 2008 and Ireland in 2008/2009.

[6] By 1990, only two US states had favorable capital requirements for mutual insurers (Zanjani, 2007).

[7] Excluded from the Solvency II regulation are very small insurers with premium income not exceeding 5 million Euros.

[8] In the EU and the US, a diversified insurer (in terms of underwriting) has to hold less capital than a specialized insurer because the correlations between the insurance business lines are assumed to be less than one (in the EU according to the Solvency II standard formula). For example, Company A which has 100 premium income in both motor and liability, *ceteris paribus*, has to hold relatively less equity capital than Companies B and C which have 200 premium income only in motor and liability, respectively. Also, Company A has to hold less equity than Companies D and E together which have only 100 premium income in motor and liability, respectively.

traditionally dominated by, for example, specialized mutual insurers which puts additional pressure on these insurers to defend their existence. Winter (1991) highlights that changes in the dominance of the organizational forms can occur quickly in the insurance industry. Thus, as a consequence of risk-based capital standards, it can be expected that mutual insurers are especially eager to expand their businesses (e.g., mergers & acquisitions (M&A), strategic alliances, new products, and new markets) to attain capital economies of scale and scope to avoid being crowded out of the insurance business (Broek et al., 2011).[9] Entering markets traditionally dominated by the other organizational form probably requires applying the same rules (pricing, risk selection, pooling, handling of agency conflicts, etc.) to offer competitive prices and to attain attractive and healthy output (Broek et al., 2011), especially since none of the organizational forms has competitive advantages regarding the amount of inputs anymore.[10,11] Otherwise, the more efficient organizational form may be able to skim off customers in these segments.

Because of the level playing field for both organizational forms (in terms of taxation and solvency margins) and the introduction of risk-based capital standards, a convergence of the production technologies of both organizational forms can be expected (Broek et al., 2011). Such a process would go hand in hand with the trend of an increasingly uniform European (i.e., due to the Internal Market and increased competition; see, e.g., Cummins et al., 2016) insurance market. Cummins et al. (2016) empirically document that higher competition in the EU life insurance sector promoted inter-country convergence in 1998–2007, leading to more homogeneity among insurers. Because today's mutual insurers tend to be a product of a bygone era with a different economic context (see, e.g., Zanjani, 2007), they may have to either demutualize or orient towards stock insurers' operations to cope with the changed economic context and to avoid being crowded out of the market (Broek et al., 2011). A.M. Best (2012) shows that the performance of stock and mutual insurers in the U.S. p/c sector was directionally aligned in 2001–2011; insurers stood out in terms of operating performance and capitalization regardless of the organizational form. Today, not all mutual insurers are small-scaled and niche-market players—some mutual insurers have large organizations offering a broad range of products and services (e.g., Crédit Agricole Assurances in France, Achmea in the Netherlands, R+V Versicherung in Germany,

9 Expanding business is also important for mutual insurers to raise capital as they are limited in using capital markets (Harrington & Niehaus, 2002).

10 Braun et al. (2015) show that mutual insurers could charge higher prices than stock insurers. However, policyholders of mutual insurers are less aware of their voting rights and rational agents would not pay for the nonrealizable component of the equity stake. In an empirical analysis of German motor vehicle liability insurance sector in 2000–2006, the authors document that prices of stock and mutual insurers are not significantly different.

11 Although the same capital requirements apply to stock and mutual insurers, differences still remain with regards to how capital is raised. Mutual insurers cannot use capital markets but are also less dependent on external fund raising compared to stock insurers, a fact that could be especially valuable during crises. These idiosyncrasies may encourage both organizational forms to hold additional capital buffers. However, the differences may likely cause different speeds in capital structure changes.

Liberty Mutual in the US; for more details see, e.g., International Cooperative and Mutual Insurance Federation (ICMIF), 2016; Federal Insurance Office, 2016). Based on this discussion, H1a may subside over time in the new economic context.

Consequently, I formulate the "convergence hypothesis" that the technologies of stock and mutual insurers converge over the long term, guaranteeing the survival of both organizational forms (H1b):

H1b: Over the long term, stock and mutual insurers' technologies converge.

3 Data and methodology

3.1 Data

The selection of the samples is oriented toward Biener and Eling (2012) and focuses on the life and non-life sectors of the two central global insurance markets. Hence, I consider life and non-life insurers that are domiciled in the U.S. and the EU (including countries from the European Economic Area and Switzerland). Merging the U.S. and EU life and non-life samples yields samples for the global insurance markets (Biener & Eling, 2012).[12] I extract data for 2002–2015 from two sources for accounting information. The data for the U.S. markets stems from Bureau van Dijk's Global Insurance Company Database (ISIS) (see, e.g., Cummins et al., 2016). The data for the EU insurers is extracted from the Insurance Reports database of A.M. Best (see, e.g., Eling & Schaper, 2017); the data for these insurers is lopsided in the ISIS database for a significant part of the sample period.[13] Due to data availability, the Czech Republic, Greece, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Poland, Slovakia, and Slovenia cannot be considered. Due to data availability, Canada cannot be considered; this would have allowed a creation of a Northern American sample as in Biener and Eling (2012). Observations with missing or extreme data, such as zero or negative total asset values, were eliminated from the samples. Furthermore, only firms for which data is available for every year are included in the final samples and only firms, which do not change their organizational form during the sample period are considered.[14] All absolute values in the samples are deflated to 2002 and converted to US dollars (USD) using

[12] The efficiency results strongly depend on the selected group of insures which shall be evaluated against each other. For example, a combined frontier of both US and EU insurers assumes that insurers from both regions are in direct competition (Biener & Eling, 2012). However, it is also reasonable to assume that competition exists only within the US market and only within the EU.

[13] In fact, the data for 2002–2013 is directly obtained from A.M. Best and the data for 2014 and 2015 stems from Bureau van Dijk's orbis insurance focus database, which relies on A.M. Best as data provider. The data is matched by the A.M. Best identification number.

[14] Otherwise, the results could be biased by stock/mutual insurers, which leave the market or prepare for (de)mutualization. For example, a mutual insurer that cannot catch-up to the common benchmark and either leaves the market or demutualizes would bias the results towards convergence; McNamara and Rhee (1992) show that increased efficiency can be the result of demutualization. In a robustness test, I also run the econometric analyses for an unbalanced sample, the results of which are consistent with the conclusions presented in this paper and are available from the author upon request.

consumer price indexes from the World Bank and exchange rates from the European Central Bank.

I differentiate the sample insurers by organizational form (stock or mutual). Additionally, I classify all insurers in the database with the organization type reciprocal exchange, non-profit company, friendly society, fraternal benefit organization, and cooperative as mutual insurers (Smith & Stutzer, 1995; Swiss Re, 2016). I exclude Lloyd's insurers, pool or insurance trusts, and insurers whose organizational form is unknown. Furthermore, I exclude insurers in run-off, insurers which stopped underwriting insurance business during the sample period, and insurers for which either only group accounts or unreliable financials are available. The final global samples consist of 431 life insurance companies (6,023 firm years) and 918 non-life insurance companies (12,758 firm years).

Table 1 presents summary statistics for the inputs, input prices, and outputs—which are used for the later efficiency analyses and which are detailed in the following—as well as key firm characteristics.

Table 1 Summary statistics

Variables	Unit	Stock and mutual insurers pooled						Stock insurers separately						Mutual insurers separately					
		Mean	Min	25%	50%	75%	Max	Mean	Min	25%	50%	75%	Max	Mean	Min	25%	50%	75%	Max
U.S.																			
Life																			
Labor(x1)	1,000s	3.90	0.00	0.46	1.32	4.13	76.93	3.72	0.00	0.44	1.29	4.03	76.93	6.16	0.19	0.75	1.90	11.17	28.69
Debt capital (x2)	bn $	12.45	0.01	0.67	2.23	8.89	225.16	11.62	0.01	0.67	2.30	8.53	225.16	22.52	0.14	0.71	1.87	15.27	164.79
Equity capital (x3)	bn $	1.34	0.01	0.16	0.41	1.30	29.40	1.24	0.01	0.16	0.40	1.24	29.40	2.53	0.03	0.09	0.64	2.34	16.31
Losses (y1 not shifted)	bn $	1.34	-0.36	0.08	0.26	1.09	27.37	1.27	-0.36	0.08	0.26	1.03	27.37	2.18	0.02	0.09	0.23	1.47	15.09
Total investments (y2)	bn $	8.64	0.02	0.65	1.76	6.71	178.12	7.74	0.02	0.63	1.73	6.69	178.12	19.56	0.16	0.92	1.94	6.75	154.44
Assets	bn $	16.44	0.03	1.02	3.20	12.30	309.10	15.34	0.03	1.01	3.21	11.73	309.10	29.92	0.19	1.15	2.62	19.22	238.54
Equity to assets	%	0.18	0.01	0.09	0.13	0.21	0.95	0.19	0.01	0.09	0.14	0.22	0.95	0.16	0.05	0.07	0.11	0.15	0.60
Non-life																			
Labor (x1)	1,000s	2.90	0.00	0.25	0.56	1.47	1,701.66	3.05	0.00	0.23	0.55	1.52	1,701.66	2.56	0.02	0.27	0.57	1.40	112.15
Debt capital (x2)	bn $	1.07	0.00	0.08	0.18	0.57	379.69	1.16	0.00	0.08	0.18	0.61	379.69	0.86	0.00	0.08	0.17	0.49	44.77
Equity capital (x3)	bn $	1.02	0.00	0.08	0.16	0.48	265.03	1.08	0.01	0.08	0.17	0.52	265.03	0.87	0.00	0.07	0.14	0.39	62.71
Losses (y1 not shifted)	bn $	0.43	-3.82	0.03	0.07	0.21	114.51	0.42	-3.82	0.03	0.07	0.21	114.51	0.44	-0.01	0.04	0.08	0.20	26.68
Total investments (y2)	bn $	1.80	0.00	0.14	0.28	0.91	536.67	1.92	0.01	0.14	0.29	0.96	536.67	1.51	0.00	0.14	0.26	0.77	99.26
Assets	bn $	2.51	0.01	0.19	0.40	1.26	802.79	2.69	0.01	0.20	0.42	1.35	802.79	2.06	0.03	0.19	0.36	1.13	138.80
Equity to assets	%	0.49	0.03	0.38	0.47	0.58	1.00	0.50	0.07	0.39	0.48	0.60	1.00	0.46	0.03	0.37	0.45	0.54	0.97
EU																			
Life																			
Labor (x1)	1,000s	1.82	0.00	0.10	0.54	1.82	134.94	2.19	0.00	0.18	0.65	2.01	134.94	0.90	0.00	0.01	0.18	1.13	7.32
Debt capital (x2)	bn $	7.49	0.00	0.37	2.11	8.06	195.09	8.43	0.00	0.46	2.11	9.16	195.09	5.15	0.00	0.14	2.12	5.82	46.53
Equity capital (x3)	bn $	0.24	0.00	0.02	0.07	0.26	4.88	0.24	0.00	0.02	0.07	0.25	4.88	0.26	0.00	0.01	0.06	0.28	4.59
Losses (y1 not shifted)	bn $	1.30	-83.50	0.04	0.31	1.24	137.04	1.44	-83.50	0.07	0.34	1.35	137.04	0.94	-2.06	0.01	0.17	1.03	14.07
Total investments (y2)	bn $	7.19	0.00	0.37	2.06	7.93	182.65	8.00	0.00	0.45	2.03	8.92	182.65	5.17	0.00	0.14	2.11	5.71	45.82
Assets	bn $	8.68	0.00	0.44	2.41	9.35	234.63	9.73	0.00	0.54	2.44	10.72	234.63	6.07	0.00	0.17	2.40	6.86	56.49
Equity to assets	%	0.07	0.00	0.02	0.04	0.06	0.95	0.07	0.00	0.02	0.04	0.07	0.95	0.07	0.00	0.02	0.04	0.06	0.79
Non-life																			
Labor (x1)	1,000s	2.30	0.00	0.12	0.44	2.09	138.96	2.62	0.00	0.15	0.60	2.39	138.96	0.73	0.00	0.05	0.18	0.43	10.05
Debt capital (x2)	bn $	1.71	0.00	0.04	0.21	0.99	82.25	1.94	0.00	0.05	0.27	1.11	82.25	0.57	0.00	0.02	0.07	0.46	8.00
Equity capital (x3)	bn $	0.56	0.00	0.02	0.07	0.33	59.90	0.61	0.00	0.02	0.08	0.37	59.90	0.29	0.00	0.02	0.05	0.15	3.78
Losses (y1 not shifted)	bn $	0.43	-6.15	0.02	0.06	0.30	30.07	0.48	-6.15	0.02	0.08	0.36	30.07	0.20	-0.03	0.01	0.03	0.13	3.64
Total investments (y2)	bn $	1.65	0.00	0.05	0.20	0.95	106.77	1.83	0.00	0.05	0.23	1.04	106.77	0.72	0.00	0.03	0.09	0.49	7.44
Assets	bn $	2.53	0.00	0.08	0.34	1.57	143.27	2.85	0.00	0.09	0.42	1.75	143.27	0.97	0.00	0.05	0.14	0.65	11.21
Equity to assets	%	0.33	0.01	0.19	0.27	0.42	0.99	0.31	0.01	0.18	0.26	0.40	0.99	0.40	0.05	0.25	0.36	0.52	0.95

3.1.1 Inputs selection

In the insurance literature, there is broad acceptance of the choice of inputs for efficiency analyses (Eling & Luhnen, 2010). I therefore use labor (x_1), debt capital (x_2), and equity capital (x_3) as input variables. The business and materials input of insurers (Cummins & Weiss, 2013) cannot be modelled separately due to data limitations and is therefore integrated into the labor input (Biener & Eling, 2012; Biener et al., 2016). The labor input (i.e., number of employees) is estimated by dividing the net operating expenses of each insurer by annual country-specific average wage rates. For insurers domiciled in the US, I obtain the state-specific wage rates from the U.S. Department of Labor. The wage rates are provided separately for life (North American Industry Classification System (NAICS) class 524113) and non-life insurers (NAICS class 524126). For all insurers domiciled in the EU, I obtain the wage rates for insurance activities from the International Labor Organization. The few missing values were either approximated by wage rates for financial intermediation activities or linear interpolation.

3.1.2 Output selection

I follow the value-added approach to measure the intangible service outputs of insurers (Cummins & Weiss, 2013). The three value-adding services of insurers are risk-pooling/risk-bearing, intermediation, and financial services related to insured losses. As a proxy for the first service (y_1), I use the present value of losses paid adjusted for the change in the provision for outstanding claims for non-life insurers (i.e., real incurred losses) and benefits paid adjusted for the change in the provision for outstanding claims for life insurers. To avoid negative numbers for this output (i.e., if the change in provisions is higher than the losses paid/claims paid in one year) I shift this variable for the complete sample period (Biener et al., 2016). The intermediation service of insurers (y_2) is represented by the total investments value. I do not model the third service output because y_1 and y_2 are highly correlated with the financial services output of insurers (Eling & Luhnen, 2010).

3.2 Methodology

3.2.1 Efficiency measurement

Efficiency can be measured following a parametric (econometric) or nonparametric (mathematical programming) approach. Both approaches are frequently used in the insurance literature (Cummins & Weiss, 2013). The main advantage of the nonparametric approach is that it is less vulnerable to specification errors (Biener et al., 2016). Consequently, I choose data envelopment analysis (DEA) originated by Charnes, Cooper, and Rhodes (1978) to determine firm technical efficiency based on firm productivity relative to the productivity of best-practice firms.

I estimate input-oriented frontiers based on the inputs and outputs defined in Section 3.1 with constant returns to scale to determine technical efficiency. Equation (1) illustrates the linear programming problem to determine technical efficiency:

$$TE_j = \min \theta_j \text{, s.t. } \lambda_j X \leq \theta_j x_j \text{, } \lambda_j Y \geq y_j \text{, } \lambda_j \geq 0 \ (j = 1,2,3......N). \tag{1}$$

TE represents Farrell's (1957) measure of technical efficiency for DMU j ($j = 1,2,...N$), N denotes the number of decision making units (DMU; i.e., insurers), M and K are the number of inputs and outputs, respectively, θ is a scalar providing a radial distance estimate, X is a $M \times N$ matrix of all inputs used, Y is a $K \times N$ matrix of all outputs produced, x_j is an $M \times 1$ input vector for DMU j, y_j is a $K \times 1$ output vector for DMU j, and λ_j is an $N \times 1$ intensity vector.

Based on the DEA methodology, I estimate metatechnology technical efficiency (MTE) for stock and mutual insurers as illustrated in Equation (2) to analyze the technology usage of stock and mutual insurers (O'Donnell et al., 2008):

$$MTE_{j,t} = \frac{Efficiency_{j,t}}{Efficiency_{j,t}^{k}} \text{, } k\{stock\ frontier;\ mutual\ frontier\}. \tag{2}$$

MTE is the metatechnology technical efficiency ratio of firm j, $Efficiency$ is the metafrontier efficiency ratio (i.e., efficiency measured against a common frontier for stock and mutual insurers), and $Efficiency^{k}$ represents efficiency measured against a frontier constituting only stock (mutual) insurers if firm j is a stock (mutual) insurer. This concept allows for different production environments among groups of firms (i.e., between the stock and mutual organizational forms) and depicts the level of homogeneity between them (Cummins et al., 2016).[15] MTE ratios of 1 suggest that the efficiency of stock and mutual insurers is not affected by the choice of the frontier (i.e., common vs. group frontier) indicating that the two organizational forms use identical technologies. Because differences in efficiency between the individual stock and mutual frontiers may be attributable to different sample sizes, I follow Cummins et al. (2004) and Biener and Eling (2012) to build size-stratified samples. Thus, each year I sort stock and mutual insurers into small, medium, and large quantiles and then randomly draw several stock insurers from the complete sample that equals the number of mutual insurers in each size quantile. To ensure robust findings, I run 200 iterations of the

[15] One requirement for the metatechnology efficiency methodology is that the groups of firms can change their production environments (i.e., switch to one of the other groups; O'Donnell et al., 2008). I believe that this is the case for the groups of stock and mutual insurers—where the production environment superficially refers to the inherent costs and benefits of each ownership types—because (1) they can technically (i.e., from a legal perspective) operate in the same market segments exposing them to the same production conditions (in reality, stock and mutual insurers jointly serve several market segments), (2) mutual insurers are able to choose a mutual holding company (MHC) structure which enables them to benefit from advantages of the stock charter (see, e.g., Erhemjamts & Leverty, 2010; NAIC, 1998), (3) stock and mutual insurers can exercise legal structure conversions and switch to the other ownership form, and (4) mutual insures can adopt stock insurer practices, increase the scale of operation, operate as full service provider, and diversify geographically as already existent in the US or some EU markets (see, e.g., Broek et al., 2011).

random selection of stock insurers (Biener & Eling, 2012). Because the econometric analyses in 3.2.2 involve the usage of lagged values, I calculate average values per year and firm based on the iterations.

3.2.2 Trends in technology usage

I analyze trends in technology usage (i.e., the methods and processes to produce outputs from inputs) over time by analyzing the developments of stock and mutual insurers' MTE ratios based on three criteria (Casu & Girardone, 2010; Cummins et al., 2016). These three criteria comprise β-convergence and σ-converge which are also discussed in economic growth theory (Barro & Sala-i-Martin, 1995) and the convergence towards identical production processes (i.e., MTE ratios of 1). The advantage of these concepts is that they consider the underlying dynamics of technology development during the sample period from which projections for the out-of-sample development could also be drawn. β-convergence is analyzed, as illustrated in Equation (3):

$$\Delta E_{j,t} = \alpha_0 + \alpha_1 Mutual + \beta_1 (\ln MTE_{j,t-1}) + \beta_2 (\ln MTE_{j,t-1}) \times Mutual + \rho \Delta E_{j,t-1} + \varepsilon_{j,t} . \quad (3)$$

$\Delta E_{j,t} = \ln(MTE_{j,t}) - \ln(MTE_{j,t-1})$, $MTE_{j,t}$ ($MTE_{j,t-1}$) is the MTE ratio of insurer j at time t $(t-1)$, $Mutual$ is a binary variable taking the value 1 if insurer j is a mutual and 0 if it is a stock, $\varepsilon_{j,t}$ is the error term, and α, β, and ρ are the parameters to be estimated. β captures the catch-up effect and a negative value of this parameter implies convergence; the greater the value, the greater the tendency of convergence. To control for differences among stock and mutual insurers, Equation (3) considers an interaction term. I estimate Equation (3) with and without a lagged dependent variable (Casu & Girardone, 2010).

I analyze σ-convergence as shown in Equation (4):

$$\Delta V_{j,t} = \alpha_0 + \alpha_1 Mutual_j + \sigma_1 V_{j,t-1} + \sigma_2 V_{j,t-1} \times Mutual_j + \rho \Delta V_{j,t-1} + \varepsilon_{j,t} . \quad (4)$$

$V_{j,t} = \ln(MTE_{j,t}) - \ln(\overline{MTE_t})$, $\overline{MTE_t}$ is the mean metatechnology technical efficiency ratio of all insurers at time t, $\Delta V_{j,t} = V_{j,t} - V_{j,t-1}$, $MTE_{j,t}$ and $\varepsilon_{j,t}$ are defined as before. α, σ, and ρ are the parameters to be estimated. σ represents the rate of convergence towards the mean MTE ratios of all insurers and a negative value of this parameter implies convergence; the greater the value the greater is the rate of convergence. I also estimate Equation (4) with and without the lagged dependent variable.

Equation (5) shows how the convergence towards MTE ratios of 1 (i.e., homogenous production processes of stock and mutual insurers) is analyzed (refer also to Appendix A):

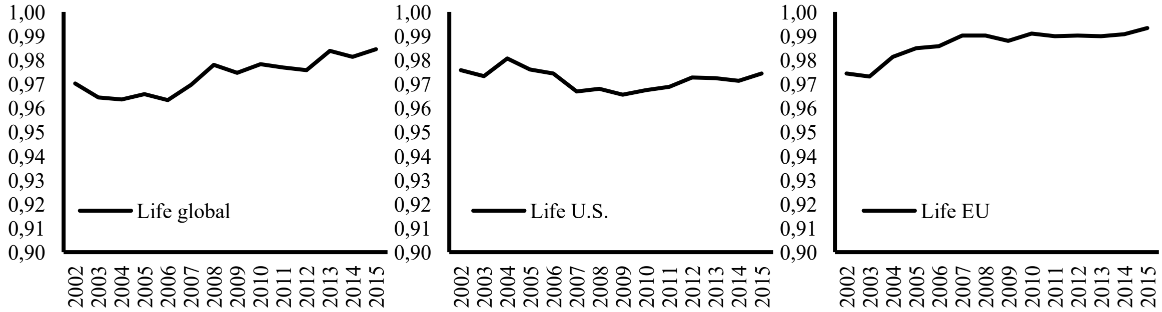
$$MTE_{j,t} = \gamma_1 + \gamma_2 Mutual_j + \gamma_3 MTE_{j,t-1} + \gamma_4 MTE_{j,t-1} \times Mutual_j + \varepsilon_{j,t} . \quad (5)$$

$\delta_S = (1-\gamma_3)$ for stock insurers and $\delta_M = (1-\gamma_3-\gamma_4)$ for mutual insurers, which capture the adjustment rate towards the state of identical production processes. The higher the value of δ, the greater the rate of convergence. Conversely, a lower or negative value implies lack of convergence or persistence of differences (Casu & Girardone, 2010; Lin & Kao, 2014).

4 Empirical results

Figure 1 presents the development of mean MTE ratios for 2002–2015 in the life sector. Figure 2 presents those ratios in the non-life sector. Appendices B and C show the annual mean MTE ratios for all samples. All mean levels are consistently lower than 1 (representing conformity of stock and mutual insurers' technologies) throughout the sample period, indicating differences in the efficiency measurement according to the metafrontier and the individual stock/mutual frontiers. This result may be set in reference with the initial hypothesis suggesting that stock and mutual insurers use different technologies and are each dominant in producing their respective outputs (Cummins et al., 1999b; Cummins et al., 2004; Biener & Eling 2012). However, Figures 1 and 2 offer several important insights. First, although the MTE ratios are lower than 1, they are considerably high, indicating only minor technology differences between stock and mutual insurers during the sample period. Cummins et al. (2016), for example, document lower cost and revenue metatechnology levels in an analysis of cross-country differences in the EU life insurance sector. Second, Figures 1 and 2 emphasize that the differences between stock and mutual insurers are subject to changes over time. For the global and EU life sectors, Figure 1 reveals an increase of the mean MTE ratios from 2002–2015. In the U.S. life sample, the yearly mean MTE ratios seem to remain high except for minor fluctuations. Interestingly, in 2005, the MTE ratios in the EU exceeded the levels for the U.S. sample.

Figure 1 Development of MTE in the life sector, 2002–2015



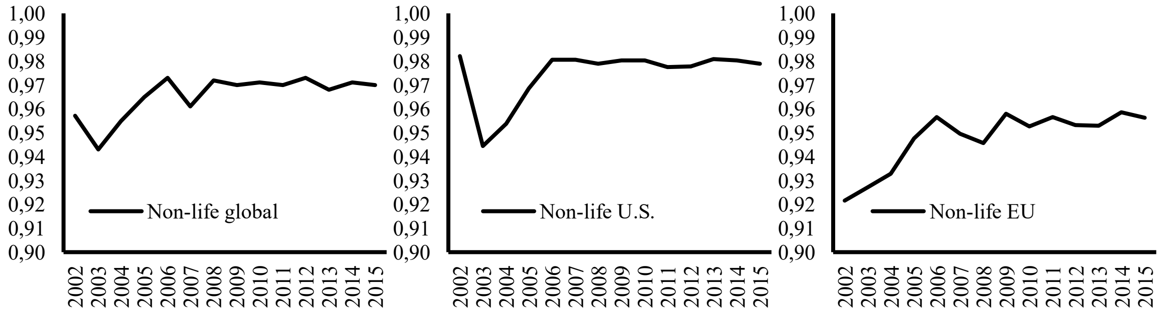
Notes: Figure 1 shows the mean MTE ratios for 2002–2015 in the life sector.

For the non-life sector, Figure 2 reveals that the MTE ratios tend to hover around 0.98 in the US sample apart from a drop in 2003–2005. The drop is traceable to a disproportionate increase, mainly in the labor input factor of the mutual insurers compared to the stock insurers in the sample. A.M. Best (2012) documents a significant divergence in stock and mutual insurers' expense ratios and net written premiums, which is relevant for the calculation of the labor input, during this period; output change remained comparable between the two organizational forms.

In the EU sample, the ratios throughout the sample period are significantly lower but increase considerably. Likewise, the MTE ratios increase in the global non-life sample; the drop in 2003–2005 in this sample seems to have been driven by the US insurers. The effect in the global sample in 2002 appears to be more intense as it captures both the convergence of EU non-life insurers and the temporary divergence of US insurers in the MTE measurement.

The results from the US market might be regarded as a benchmark for the degree of convergence that could be expected for stock and mutual insurers in the non-life sector. This is because the changes in the operating conditions outlined in chapter 2 were present in this market since the early 1990s and the MTE ratios do not change much during the sample period, except for the mentioned drop. This would suggest that convergence might not be perfectly (i.e., MTE ratios of 1) attributable to persistent differences between stock and mutual insurers—for example, the speed of raising new capital.

Figure 2 Development of MTE in the non-life sector, 2002–2015



Notes: Figure 2 shows the mean MTE ratios for 2002–2015 in the non-life sector.

Taken together, the results from the graphical analysis are first preliminary evidence of some convergence in parts of the insurance industry. To dig deeper into the development of stock and mutual insurers' technology usage from an econometric perspective, I present the results for the tests for β-convergence (Equation 3) and σ-convergence (Equation 4) in Tables 2 and 3, respectively.

Table 2 β-convergence of MTE

Coefficients	Equation (3) without lagged dependent variable			Equation (3)		
Life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
β_1	-0.1791***	-0.2210***	-0.3679***	-0.1586***	-0.1885***	-0.3999***
	(0.0072)	(0.0115)	(0.0122)	(0.0072)	(0.0125)	(0.0103)
β_2	-0.0748	0.1603	0.2256***	-0.0011	0.1505	0.2715***
	(0.2204)	(0.1003)	(0.0723)	(0.2085)	(0.1007)	(0.0542)
ρ				-0.2113***	-0.1359***	-0.0533***
				(0.0132)	(0.0187)	(0.0126)
α_0	-0.0024	-0.0070***	0.0002	-0.0018	-0.0059***	0.0008
	(0.0115)	(0.0009)	(0.0058)	(0.0111)	(0.0009)	(0.0043)
α_1	-0.0748	0.1603	0.2256***	-0.0011	0.1505	0.2715***
	(0.2204)	(0.1003)	(0.0723)	(0.2085)	(0.1007)	(0.0542)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0977	0.1124	0.2554	0.1642	0.1279	0.4123
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
β_1	-0.4710***	-0.4891***	-0.3512***	-0.4745***	-0.4895***	-0.2907***
	(0.0079)	(0.0105)	(0.0113)	(0.0053)	(0.0070)	(0.0123)
β_2	0.3878***	-0.0043	0.1069***	0.3797***	-0.0062	0.0984***
	(0.0210)	(0.0466)	(0.0307)	(0.0125)	(0.0273)	(0.0301)
ρ				0.0370***	0.0425***	-0.2304***
				(0.0053)	(0.0069)	(0.0141)
α_0	-0.0311***	-0.0171***	-0.0495***	-0.0321***	-0.0122***	-0.0371***
	(0.0073)	(0.0007)	(0.0078)	(0.0044)	(0.0004)	(0.0077)
α_1	0.0139***	0.0120***	0.0063**	0.0058***	0.0069***	0.0031
	(0.0012)	(0.0012)	(0.0027)	(0.0007)	(0.0008)	(0.0027)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2295	0.2429	0.1887	0.4718	0.4960	0.2452

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

Table 2 shows a negative and significant β-coefficient for stock insurers (β_1) in the global sample as well as in the individual US and EU samples. This result holds for the life and non-life sector and is also robust across the two models (i.e., Equation (3) with and without lagged dependent variable). Table 2 suggests differences in β-convergence among stock and mutual insurers in the EU non-life sample as well as the global and EU life samples as the coefficient of the interaction term (β_2) is significant in the respective regression models. The corresponding β-coefficients for mutual insurers $(\beta_1 + \beta_2)$ are still negative in all cases but are lower than the ones for stock insurers. Overall, the results provide evidence for β-convergence suggesting that stock and mutual insurers that have the largest gaps in MTE ratios show higher catch-up growth than insurers with smaller technology gaps (see, e.g., Cummins et al., 2016). Thus, the analysis of β-convergence supports H1b; especially, lagging stock and mutual insurers (probably, small niche players) catch up to the common frontier. However, the results also show that mutual insurers have lower β-convergence than stock insurers in some market segments. Thus, in a longer-term perspective the identified convergence trend could produce a dominance situation if stock insurers on average show consistently higher catch-up effects than mutual insurers. The differences in β-convergence may also indicate the persistence of some differences among organizational forms.

Table 3 shows the results for σ-convergence, which measures whether stock and mutual insurers' MTE ratios converge towards the common average. Table 3 reports a consistently negative and significant σ-coefficient for stock insurers (σ_1) in all samples (global, US, EU) for the life and non-life sectors and for the two models. For mutual insurers, a different σ-coefficient (as indicated by a significant σ_2) is revealed only in the EU life and in the global and EU non-life samples. Although the corresponding coefficients $(\sigma_1 + \sigma_2)$ are lower than for stock insurers, they are all still negative, providing evidence for convergence. Thus, the results suggest that the dispersion of MTE ratios around the common averages decreased during the sample period. This reduced dispersion also supports the expectation of converging technologies of stock and mutual insurers (H1b). However, as discussed for β-convergence, the lower σ-coefficient of mutual insurers in some market segments suggests the need for further monitoring.

Table 3 σ-convergence of MTE

Coefficients	Equation (4) without lagged dependent variable			Equation (4)		
Life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ_1	-0.1799***	-0.2199***	-0.3758***	-0.1596***	-0.1877***	-0.3977***
	(0.0072)	(0.0114)	(0.0124)	(0.0072)	(0.0125)	(0.0106)
σ_2	0.0325	0.1582	0.2232***	0.0594	0.1456	0.2092***
	(0.1283)	(0.0994)	(0.0597)	(0.1203)	(0.0994)	(0.0468)
ρ				-0.2110***	-0.1356***	-0.0512***
				(0.0132)	(0.0187)	(0.0127)
α_0	0.0014	-0.0006	0.0038	0.0007	-0.0005	0.0042
	(0.0114)	(0.0008)	(0.0057)	(0.0110)	(0.0008)	(0.0043)
α_1	0.0018	0.0004	0.00004	-0.0011	0.0003	-0.0008
	(0.0035)	(0.0031)	(0.0011)	(0.0033)	(0.0032)	(0.0008)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0988	0.1118	0.2578	0.1649	0.1273	0.4027
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ_1	-0.4731***	-0.4793***	-0.3530***	-0.4686***	-0.4879***	-0.2847***
	(0.0081)	(0.0106)	(0.0115)	(0.0057)	(0.0072)	(0.0124)
σ_2	0.3495***	-0.0179	0.1115***	0.3350***	0.0415*	0.0894***
	(0.0187)	(0.0380)	(0.0298)	(0.0118)	(0.0231)	(0.0293)
ρ				0.0134**	0.0253***	-0.2343***
				(0.0057)	(0.0071)	(0.0141)
α_0	-0.0179***	-0.0040***	-0.0334***	-0.0231***	-0.0021***	-0.0248***
	(0.0068)	(0.0006)	(0.0077)	(0.0044)	(0.0004)	(0.0076)
α_1	0.0028***	0.0121***	0.00003	-0.0052***	0.0062***	-0.0024
	(0.0011)	(0.0012)	(0.0024)	(0.0007)	(0.0008)	(0.0024)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2269	0.2381	0.1864	0.4405	0.4841	0.2432

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

Despite the evidence for β- and σ-convergence, I analyze whether the MTE ratios converge towards 1 as this result would indicate that stock and mutual insurers come to use same technologies. In other words, β- and σ-convergence without evidence for convergence towards 1 could mean that the MTE ratios become closer in the sample but still persist at values smaller than 1 (i.e., differences in the technologies persist). To analyze convergence of MTE ratios towards 1, I estimate Equation (4) and present the results in Table 4.

Table 4 presents significant and positive γ_3-coefficients for stock insurers in all samples of the life and non-life sectors. For the US and EU non-life as well as the global and EU life samples, Table 4 reports a significant coefficient of the interaction term (γ_4)

indicating differences between stock and mutual insurers. The corresponding coefficients for mutual insurers $(\gamma_3 + \gamma_4)$ are still positive but higher than for stock insurers; in the partial adjustment model, a higher coefficient indicates slower adjustment. Nevertheless, the coefficients for both stock and mutual insurers correspond to positive δ-values $(\delta_S = 1 - \gamma_2; \delta_M = 1 - \gamma_2 - \gamma_3)$ consistently indicating convergence towards 1 but the higher δ_S-values suggest higher convergence rates of stock insurers (refer to Appendix D). In addition, although the results from partial adjustment model propose convergence towards identical production processes (i.e., MTE ratios of 1), observations from the graphical analysis and theoretical arguments suggest convergence may not be perfect.

Table 4 Convergence of MTE towards 1

Coefficients	Equation (5)			Equation (5)		
	Life			*Non-life*		
	Global	*US*	*EU*	*Global*	*US*	*EU*
γ_1	0.1623***	0.1982***	0.3449***	0.4190***	0.4395***	0.2850***
	(0.0107)	(0.0108)	(0.0126)	(0.0095)	(0.0100)	(0.0116)
γ_2	0.0905	-0.1401	-0.1975***	-0.3372***	0.0405	-0.0942***
	0.0905	-0.1401	-0.1975***	-0.3372***	0.0405	-0.0942***
γ_3	0.8356***	0.7958***	0.6555***	0.5534***	0.5456***	0.6741***
	(0.0068)	(0.0111)	(0.0118)	(0.0078)	(0.0103)	(0.0110)
γ_4	-0.0888	0.1441*	0.2001***	0.3490***	-0.0304	0.0997***
	(0.1632)	(0.0873)	(0.0637)	(0.0208)	(0.0416)	(0.0300)
N	5,590	2,910	2,671	11,830	7,139	4,421
Adj. R^2	0.7434	0.6452	0.5779	0.3946	0.3326	0.5359

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

As a whole, the econometric results provide evidence for the convergence hypothesis (H1b) that the technologies of stock and mutual insurers converge over the long term in the changed economic context. However, although the econometric results are distinct, the results also emphasize not only differences between the life and non-life sector but also between the US and EU. Whilst the average MTE ratios are high in the life sector throughout the sample period, they are notably lower in the EU non-life sector. The differences between life and non-life may be due to more degrees of freedom in the non-life sector (Huang & Eling 2013; Eling & Schaper, 2017). In addition, in some market segments the convergence rates differ among stock and mutual insurers. This may be because of some inherent differences between the organizational forms. In the EU, differences in the legal opportunities for M&A and cross-border activities still exist in some member countries (Broek et al., 2011). Furthermore, although diversification among different insurance lines can be excepted from the introduction of risk-based capital standards, it is still ambiguous whether stock and mutual insurers continue to serve different clients (e.g., commercial vs. non-commercial; see, e.g., Biener & Eling, 2012). Thus, dominance/convergence among stock and mutual insurers should be further monitored and analyzed. In reference to the ESH, my results suggest that the dominance of the organizational forms in different market segments may decline. Mutual insurers may be compelled to progressively operate like stock insurers (e.g., takeover characteristics, pricing mechanisms, and management techniques).

5 Conclusions

I propose and empirically test the convergence hypothesis (i.e., convergence of stock and mutual insurers' technologies). I find evidence for β- and σ-convergence of stock and mutual insurers' metatechnology technical efficiency levels for 2002–2015 in sectors of the US and EU insurance markets. These results suggest that in the changed operating environment (particularly, elimination of state aid for the mutual organizational form and introduction of risk-based capital standards) the two organizational forms converge. Especially, mutual insurers may have to orient towards the stock organizational form, which may increase the homogeneity among stock and mutual insurers.

However, as initially discussed, the direct causes of the convergence trends cannot be identified, which is a central limitation of many convergence studies. Particularly, the documented differences in the convergence movements among the organizational forms, geographical areas, as well as the life/non-life sectors, offer a variety of directions for future research. The relationship between the amount of competition, capital requirements and the development of efficiency could be analyzed across industries and countries (see, e.g., Matousek, Rughoo, Sarantis, & Assaf, 2015; Cummins et al., 2016). The study could be also expanded to analyze convergence in other insurance lines. Similar to other studies, the results presented here are limited by lack of data. Thus, it would be interesting to continue monitoring the development of stock and mutual insurers' efficiency once additional firm-year data becomes available. It would also be interesting to analyze the development of cost (revenue) efficiency over time if data for individual prices of stock and mutual insurers' inputs (outputs) are available. Furthermore, it may be interesting to study mutual firm behavior in terms of size and group structure (i.e., the mutual holding company structure) and link this to efficiency (see, e.g., Cummins & Xie, 2013).

This analysis also emphasizes that future research should focus on dynamic efficiency settings while considering the operating environment (see, e.g., Zanjani, 2007; Huang & Eling, 2013; Eling & Schaper, 2017) in order to better understand firm behavior. In this regard, future research could, for example, analyze the resilience and response to endogenous/exogenous turmoil of stock and mutual insurers to arrive at further insights on situational dominance (see, e.g., Fukuyama, 1997; Tsionas, Assaf, & Matousek, 2015).

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Appendix A

Specification of partial adjustment model

I specify partial adjustment models to analyze the association between organizational form and evolution of efficiency. Equation (A1) illustrates a standard partial adjustment model for panel data (see, e.g., Pesaran, 2015):

$$Y^{*}_{j,t} = a_j + bX_{j,t} + \varepsilon_{j,t}\,. \tag{A1}$$

Y^{*} is the desired level of any decision making variable of firm j at time t, a is a constant term, X is a vector of factors related to costs and benefits of operating at the desired level for firm j at time t, b is a vector of coefficients, and ε is the disturbance term. In general, the desired level is not observable and may also change over time. However, in the efficiency context the desired level is known because all companies pursue full efficiency (Casu & Girardone, 2010):

$$Efficiency^{*}_{j,t} = Efficiency_{\max}\,. \tag{A2}$$

Equation (A2) considers no disturbance term because it represents an equilibrium relation which renders the disturbance term redundant (Cheng & Weiss, 2012). Cheng and Weiss (2012) define partial adjustment models to analyze the adjustment speeds of stock and mutual insurers to desired capital structure. Equation (A3) recognizes that adjustment costs prevent each insurer from immediately achieving the desired level of efficiency. Thus, improving efficiency (i.e., eliminating inefficiency) is an adjustment process:

$$Efficiency_{j,t} - Efficiency_{j,t-1} = \delta\left[Efficiency^{*}_{j,t} - Efficiency_{j,t-1}\right] + \varepsilon_{j,t}\,,\ 0 < \delta \leq 1\,. \tag{A3}$$

Equation (A3) considers a disturbance term as the adjustment process may be imperfect (Cheng & Weiss, 2012). $\delta = 1$ means that the insurer instantaneously adjusts to the desired efficiency level in the specified period. Usually, insurers only partially ($0 < \delta < 1$) close the gap between the actual and desired efficiency level due to technological rigidities, habit inertia, resource constraints, institutional controls, regulations, and adjustment costs (Lin, 1986). Thus insurers, must trade adjustment costs against the costs of operating inefficiently over time (Casu & Girardone, 2010). Substituting Equation (A2) into Equation (A3) and applying some simplifications yields the following model, which shows how the observed efficiency of insurer i at time t is determined:

$$Efficiency_{j,t} = \delta Efficiency_{\max} + (1-\delta) Efficiency_{j,t-1} + \varepsilon_{j,t}\,. \tag{A4}$$

To account for different adjustment speeds of stock (s) and mutual (m) insurers in the model, I differentiate Equation (A4) according to the organizational form:

$$Efficiency_{s,j,t} = \delta_s Efficiency_{\max} + (1-\delta_s) Efficiency_{s,j,t-1} + \varepsilon_{s,j,t}\,, \tag{A4.1}$$

$$Efficiency_{m,j,t} = \delta_m Efficiency_{\max} + (1-\delta_m) Efficiency_{m,j,t-1} + \varepsilon_{m,j,t}\,. \tag{A4.2}$$

Merging Equations (A4.1) and (A4.2) and replacing $Efficiency^*$ by the value 1 in line with the efficiency measurement according to Farrell (1957) who defines efficiency on [0;1], where unity represents full efficiency, yields the following pooled model:

$$Efficiency_{j,t} = \gamma_1 + \gamma_2 D_M + \gamma_3 Efficiency_{j,t-1} + \gamma_4 Efficiency_{j,t-1} D_M + \varepsilon_{j,t}\,. \tag{A5}$$

$\delta = (1-\gamma_2)$, $\delta_s = (1-\gamma_2-\gamma_4)$, and D_M is a binary variable which takes the value 1 if insurer j operates as mutual insurer. If γ_4 is significantly different from zero, mutual insurers adjust to the desired level of efficiency at different speed. If $\gamma_4 < 0$ then mutual insurers adjust more quickly to the desired level of efficiency. Equation (A5) can also be adopted to analyze convergence towards MTE ratios of 1.

Appendix B

Mean metatechnology technical efficiency life

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2002–2015
Global															
Austria	0.9845	0.9823	0.9780	0.9796	0.9841	0.9804	0.9863	0.9761	0.9808	0.9831	0.9873	0.9884	0.9884	0.9931	0.9837
Belgium	0.9516	0.8412	0.8598	0.9185	0.8551	0.9730	0.9227	0.9271	0.9027	0.9784	0.9338	0.9142	0.9776	0.9707	0.9233
Denmark	0.9897	0.9791	0.9877	0.9861	0.9896	0.9938	0.9958	0.9948	0.9966	0.9970	0.9984	0.9995	0.9974	0.9984	0.9931
Finland	0.9897	0.9782	0.9788	0.9815	0.9884	0.9886	0.9882	0.9902	0.9910	0.9896	0.9956	0.9906	0.9866	0.9877	0.9875
France	0.9864	0.9879	0.9845	0.9879	0.9875	0.9859	0.9884	0.9889	0.9903	0.9875	0.9898	0.9904	0.9891	0.9920	0.9883
Germany	0.9699	0.9649	0.9724	0.9798	0.9811	0.9869	0.9896	0.9876	0.9925	0.9931	0.9929	0.9931	0.9930	0.9945	0.9851
Ireland	0.9768	0.9565	0.9593	0.9565	0.9003	0.9024	0.9387	0.9512	0.9596	0.9519	0.9640	0.9594	0.9710	0.9683	0.9511
Italy	0.9881	0.9691	0.9700	0.9687	0.9739	0.9699	0.9696	0.9750	0.9881	0.9917	0.9915	0.9902	0.9899	0.9918	0.9805
Netherlands	0.9816	0.9778	0.9744	0.9682	0.9694	0.9906	0.9924	0.9916	0.9950	0.9957	0.9955	0.9944	0.9940	0.9956	0.9869
Portugal	0.9900	0.9812	0.9810	0.9865	0.9831	0.9956	0.9932	0.9991	1.0000	1.0000	0.9999	0.9991	0.9984	0.9987	0.9933
Spain	0.9770	0.9746	0.9767	0.9823	0.9853	0.9890	0.9776	0.9749	0.9907	0.9904	0.9889	0.9836	0.9904	0.9918	0.9838
Switzerland	0.9609	0.9602	0.9582	0.9583	0.9592	0.9696	0.9675	0.9750	0.9860	0.9779	0.9814	0.9841	0.9840	0.9761	0.9713
United Kingdom	0.9193	0.8757	0.9828	0.9825	0.9850	0.9926	0.9933	0.9897	0.9777	0.9796	0.9761	0.9633	0.9277	0.9440	0.9635
U.S.	0.9679	0.9626	0.9548	0.9536	0.9483	0.9556	0.9707	0.9652	0.9671	0.9640	0.9617	0.9783	0.9730	0.9778	0.9643
Total	0.9703	0.9645	0.9637	0.9658	0.9634	0.9697	0.9779	0.9746	0.9783	0.9769	0.9758	0.9839	0.9813	0.9845	0.9736
U.S.															
U.S.	0.9301	0.9291	0.9377	0.9284	0.9240	0.9198	0.9359	0.9461	0.9414	0.9442	0.9404	0.9471	0.9408	0.9399	0.9361
Total	0.9301	0.9291	0.9377	0.9284	0.9240	0.9198	0.9359	0.9461	0.9414	0.9442	0.9404	0.9471	0.9408	0.9399	0.9361
EU															
Austria	0.9158	0.9392	0.9968	0.9962	0.9983	0.9991	0.9957	0.9899	0.9900	0.9873	0.9915	0.9935	0.9921	0.9956	0.9844
Belgium	0.8771	0.8238	0.8966	0.9237	0.8975	0.9833	1.0000	0.9120	0.9590	0.9949	0.9838	0.9611	0.9958	0.9977	0.9433
Denmark	0.9897	0.9827	0.9898	0.9873	0.9905	0.9942	0.9972	0.9954	0.9964	0.9970	0.9978	0.9985	0.9974	0.9982	0.9937
Finland	0.9955	0.9952	0.9909	0.9963	0.9955	0.9940	0.9937	0.9883	0.9867	0.9893	0.9904	0.9904	0.9954	0.9869	0.9920
France	0.9893	0.9853	0.9845	0.9904	0.9879	0.9883	0.9899	0.9879	0.9878	0.9877	0.9880	0.9883	0.9901	0.9941	0.9885
Germany	0.9700	0.9719	0.9811	0.9844	0.9844	0.9904	0.9923	0.9909	0.9936	0.9933	0.9937	0.9936	0.9942	0.9958	0.9878
Ireland	0.9797	0.9703	0.9573	0.9636	0.9929	0.9634	0.9644	0.9560	0.9653	0.9518	0.9636	0.9572	0.9739	0.9675	0.9662
Italy	0.9720	0.9777	0.9876	0.9926	0.9884	0.9859	0.9784	0.9761	0.9755	0.9648	0.9600	0.9637	0.9694	0.9938	0.9776
Netherlands	0.9878	0.9833	0.9816	0.9789	0.9747	0.9913	0.9953	0.9958	0.9971	0.9956	0.9939	0.9961	0.9965	0.9875	0.9897
Portugal	0.9895	0.9858	0.9826	0.9850	0.9935	0.9958	0.9954	1.0000	0.9995	0.9965	0.9999	1.0000	0.9979	0.9984	0.9943
Spain	0.9916	0.9794	0.9815	0.9856	0.9904	0.9935	0.9856	0.9838	0.9913	0.9896	0.9904	0.9912	0.9904	0.9948	0.9885
Switzerland	0.9768	0.9789	0.9742	0.9822	0.9786	0.9862	0.9818	0.9787	0.9815	0.9718	0.9742	0.9708	0.9730	0.9703	0.9771
United Kingdom	0.9165	0.9009	0.9827	0.9824	0.9859	0.9938	0.9904	0.9792	0.9811	0.9835	0.9821	0.9645	0.9569	0.9628	0.9689
Total	0.9744	0.9732	0.9814	0.9851	0.9857	0.9903	0.9902	0.9878	0.9909	0.9898	0.9902	0.9898	0.9908	0.9933	0.9866

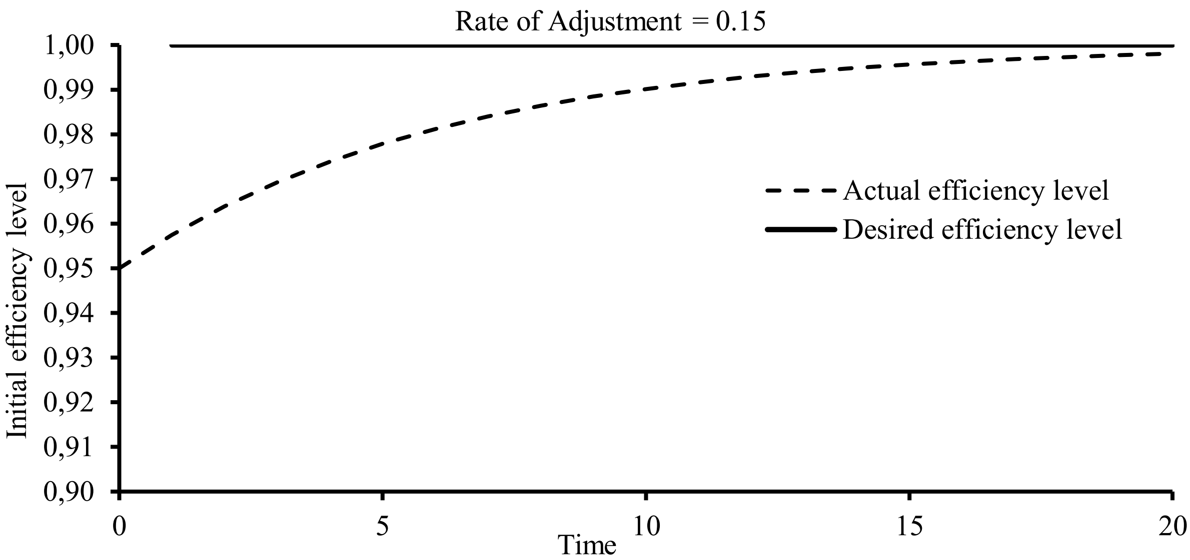
Appendix C

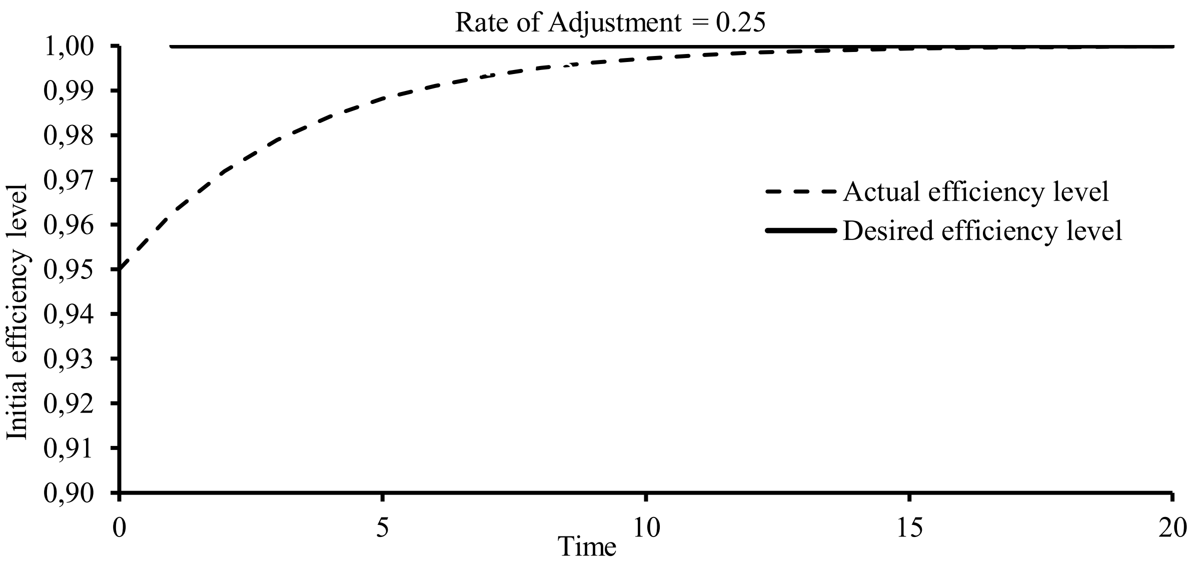
Mean metatechnology technical efficiency non-life

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2002–2015
Global															
Austria	0.9661	0.9621	0.9452	0.9482	0.9753	0.9411	0.9535	0.9381	0.9484	0.9611	0.9532	0.8897	0.9390	0.9108	0.9451
Belgium	0.9777	0.9375	0.9698	0.9803	0.9833	0.9712	0.9723	0.9810	0.9780	0.9848	0.9853	0.9826	0.9918	0.9900	0.9773
Denmark	0.9764	0.9304	0.9509	0.9870	0.9912	0.9738	0.9871	0.9758	0.9683	0.9728	0.9867	0.9783	0.9839	0.9891	0.9751
Finland	0.9649	0.9330	0.9530	0.9714	0.9806	0.9605	0.9823	0.9787	0.9818	0.9808	0.9758	0.9680	0.9756	0.9819	0.9706
France	0.9334	0.9235	0.9443	0.9728	0.9744	0.9640	0.9750	0.9781	0.9816	0.9787	0.9780	0.9756	0.9754	0.9758	0.9665
Germany	0.9602	0.9425	0.9577	0.9693	0.9768	0.9637	0.9738	0.9731	0.9785	0.9771	0.9786	0.9698	0.9780	0.9757	0.9696
Ireland	0.9516	0.9384	0.9469	0.9120	0.9155	0.9226	0.9475	0.9425	0.9476	0.9608	0.9608	0.9451	0.9529	0.9720	0.9440
Italy	0.9568	0.9486	0.9505	0.9885	0.9938	0.9875	0.9943	0.9943	0.9945	0.9921	0.9881	0.9598	0.9852	0.9808	0.9796
Netherlands	0.9618	0.9526	0.9428	0.9759	0.9808	0.9438	0.9706	0.9626	0.9616	0.9445	0.9621	0.9579	0.9707	0.9779	0.9618
Portugal	0.9609	0.9573	0.9755	0.9966	0.9910	0.9687	0.9869	0.9820	0.9905	0.9936	0.9926	0.9943	0.9967	0.9944	0.9844
Spain	0.9681	0.9704	0.9693	0.9825	0.9850	0.9812	0.9848	0.9852	0.9848	0.9810	0.9770	0.9842	0.9768	0.9737	0.9789
Sweden	0.9797	0.9743	0.9827	0.9876	0.9855	0.9758	0.9831	0.9865	0.9892	0.9799	0.9814	0.9809	0.9846	0.9828	0.9824
Switzerland	0.9561	0.9578	0.9698	0.9864	0.9820	0.9808	0.9852	0.9794	0.9863	0.9751	0.9909	0.9770	0.9899	0.9826	0.9785
United Kingdom	0.9313	0.9231	0.9401	0.9495	0.9519	0.9467	0.9610	0.9577	0.9639	0.9641	0.9709	0.9744	0.9709	0.9663	0.9552
U.S.	0.9845	0.9077	0.9301	0.9659	0.9818	0.9845	0.9818	0.9827	0.9857	0.9835	0.9846	0.9869	0.9874	0.9854	0.9737
Total	0.9735	0.9218	0.9402	0.9672	0.9786	0.9765	0.9789	0.9789	0.9821	0.9800	0.9817	0.9812	0.9833	0.9813	0.9718
U.S.															
U.S.	0.9343	0.9368	0.9242	0.9013	0.9118	0.8990	0.9127	0.9112	0.9086	0.8825	0.9003	0.8967	0.9025	0.8919	0.9082
Total	0.9343	0.9368	0.9242	0.9013	0.9118	0.8990	0.9127	0.9112	0.9086	0.8825	0.9003	0.8967	0.9025	0.8919	0.9082
EU															
Austria	0.9032	0.8479	0.8881	0.8840	0.9460	0.9070	0.8327	0.8437	0.8634	0.8834	0.8661	0.8843	0.9088	0.8737	0.8809
Belgium	0.9288	0.9014	0.9111	0.9454	0.9356	0.9468	0.9258	0.9579	0.9602	0.9733	0.9633	0.9583	0.9625	0.9590	0.9446
Denmark	0.9317	0.9090	0.9547	0.9578	0.9720	0.9614	0.9785	0.9653	0.9701	0.9698	0.9600	0.9646	0.9673	0.9746	0.9601
Finland	0.9622	0.9734	0.9621	0.9694	0.9782	0.9744	0.9831	0.9590	0.9598	0.9524	0.9605	0.9454	0.9495	0.9646	0.9638
France	0.9198	0.9369	0.9308	0.9414	0.9581	0.9610	0.9619	0.9650	0.9588	0.9637	0.9595	0.9561	0.9623	0.9623	0.9526
Germany	0.9141	0.9174	0.9239	0.9381	0.9466	0.9475	0.9422	0.9566	0.9520	0.9563	0.9521	0.9537	0.9583	0.9580	0.9441
Ireland	0.9305	0.9130	0.9107	0.8961	0.9124	0.9204	0.8917	0.9582	0.9414	0.9500	0.9045	0.9059	0.9174	0.9245	0.9196
Italy	0.9043	0.8863	0.9260	0.9660	0.9832	0.9691	0.9705	0.9837	0.9799	0.9885	0.9692	0.9580	0.9750	0.9846	0.9601
Netherlands	0.9364	0.9513	0.9369	0.9470	0.9558	0.9114	0.9175	0.9267	0.9141	0.9129	0.9340	0.9312	0.9284	0.9430	0.9321
Portugal	0.8837	0.9199	0.9326	0.9700	0.9696	0.9785	0.9764	0.9706	0.9585	0.9683	0.9655	0.9696	0.9781	0.9775	0.9585
Spain	0.9484	0.9672	0.9591	0.9755	0.9813	0.9794	0.9718	0.9738	0.9684	0.9655	0.9580	0.9651	0.9630	0.9561	0.9663
Sweden	0.9473	0.9516	0.9671	0.9731	0.9519	0.9432	0.9341	0.9523	0.9459	0.9494	0.9565	0.9837	0.9885	0.9588	0.9572
Switzerland	0.9438	0.9497	0.9656	0.9840	0.9843	0.9880	0.9831	0.9841	0.9796	0.9888	0.9909	0.9710	0.9882	0.9816	0.9771
United Kingdom	0.8965	0.9136	0.9173	0.9347	0.9489	0.9194	0.9237	0.9401	0.9339	0.9380	0.9485	0.9444	0.9527	0.9458	0.9329
Total	0.9216	0.9272	0.9329	0.9476	0.9566	0.9495	0.9457	0.9578	0.9527	0.9565	0.9533	0.9530	0.9586	0.9563	0.9478

Appendix D

Convergence towards 1 with different rates of adjustment (δ)





Curriculum Vitae

PERSONAL INFORMATION

Name: Philipp Schaper
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EDUCATION

01/2018–01/2018	**University of Georgia**, United States *Visiting Ph.D. Student in the Risk Management and Insurance Department*
06/2015–07/2015	**Global School in Empirical Research Methods**, Switzerland *Summer School*
02/2015–present	**University of St. Gallen**, Switzerland *Ph.D. Candidate in Management*
08/2013–09/2014	**University of St Andrews**, Scotland *M.Sc. Finance*
10/2010–08/2013	**Technische Hochschule Köln**, Germany *B.Sc. Insurance and Actuarial Science*
09/2010–01/2013	**Chamber of Industry and Commerce**, Germany *Apprenticeship Management Assistant for Insurance and Finance*

PROFESSIONAL EXPERIENCE

11/2014–present	**University of St. Gallen**, Switzerland *Project Manager and Research Assistant*
08/2011–08/2013	**Gothaer Asset Management AG**, Germany *Student Trainee Front Office Fixed Income*
09/2010–08/2011	**Gothaer Insurance Group**, Germany *Student Trainee Financial Lines Underwriting*

AWARDS

2014	Sir Lee Quo-Wei Postgraduate Prize in Finance, awarded to the top student in the Finance program of the University of St Andrews